PROCEEDINGS
OF
THE TENTH U.S.-JAPAN WORKSHOP
ON GLOBAL CHANGE:
CLIMATE AND WATER

January 15-17, 2003
The Beckman Center
Irvine, CA

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Foreword

This workshop was the 10th in a series of U.S.-Japan Workshops on Global Change Research held under the framework of the *U.S.-Japan Agreement on Cooperation in Research and Development in Science and Technology*. These workshops contribute to the implementation of global change research activities, fostered by the scientists of Japan and the United States, through information exchanges and discussions which promote long-term collaborations that benefit society.

The 10th U.S.-Japan Workshop focused on the topic of Climate and Water. The workshop was held at the Beckman Center in Irvine, California on January 15-17, 2003.

Sixty individuals participated in the Workshop, including researchers, scientists, and science managers from universities, government agencies and ministries and national institutions of both Japan and the United States. The workshop provided an opportunity for these individual to forge new linkages and initiate new research activities in areas that will benefit both countries. The workshop helped to identify where new opportunities exist for collaborative research based on a review of recent scientific and programmatic developments. The priority science areas of long-term climate and water cycle variability and change, prediction of water variability on monthly, seasonal and annual time scales, applications of climate information to the water resource sector, observations, modeling, and assessments were highlighted. The discussions helped to strengthen bilateral collaboration in these areas and identified ways in which Japan and the United States could advance research bilaterally and through existing international organizations and frameworks.

A report by the Co-convenors—Rick Lawford, GAPP Program Manager; and Taikan Oki, Research Institute for Humanity and Nature—follows, along with detailed working group reports.

JOINT REPORT

U.S.-Japan Workshop on Global Change
Co-Convener's Report

Co-conveners:

Taikan Oki
Associate Professor
Research Institute for Humanity and Nature
Kyoto, Japan

Rick Lawford
Program Manager, GEWEX Americas Prediction Project
Director, Global Water Cycle Program Office
Washington, DC, USA

Summary:

The 10th U.S.-Japan Workshop on Global Change was designed to bring Japanese and American scientists together to exchange views on research priorities and needs related to the effects of the water cycle on climate and the effects of climate variability and change on water resources. The workshop had two main sessions: one dealing with the key scientific issues related to the understanding and prediction of water cycle variability and the application of this knowledge to water management, and a second session to consider the capabilities of observational systems, models, and decision support resources for addressing these research priorities.

Keynote presentations summarizing the major issues were given in advance of each of the work sessions. The keynote speakers reviewing the scientific issues included Professor Dennis Lettenmaier, the GEWEX representative to the Global Water System Project, who reviewed long-term climate and water cycle variability and change; Professor Masahide Kimoto who gave an overview of the physical basis for making predictions of climate and water cycle variability on monthly to annual time scales, and Professor Soroosh Sorooshian, the Chair of the GEWEX Scientific Steering Group, who described the prospects and challenges for using the results of hydroclimatic research in water resources management. The second set of introductory lecturers included Professor Kenji Nakamura, senior NASDA scientist for the GPM, who reviewed the Global Precipitation Measurement (GPM) Mission, a major observational initiative of Japan and the USA; Professor Roni Avissar, chair of the U.S. Global Water Cycle Scientific Steering Group, who described the characteristics of a new model for predicting water cycle variability; and Professor Kuniyoshi Tackeuchi, President of IAHS, who reviewed international activities related to global water resource assessments and opportunities for U.S.-Japan cooperation in this area.

The first set of working group sessions addressed research needs related to climate variability and change, predictions of water cycle variability, and applications of climate information in water resources. The second set of working groups on Thursday afternoon and Friday morning addressed the roles of observations, modeling capabilities and assessments in relation to the priorities raised in the first working group sessions. Reports from the individual sessions are summarized in the following pages.

The last afternoon of the workshop was devoted to a plenary discussion to identify ways in which the priority issues could be addressed through U.S.-Japan collaboration. Based on these discussions the plenary session recommended that:

1. The United States and Japan should:
    a) provide leadership for water cycle observations and data integration centers in support of water cycle research through international frameworks, such as IGOS-P, WSSD, and UNFCCC/SBSTA/COP.
    b) promote studies focusing on anthropogenic influences on global and regional water cycles.
    c) promote studies on reducing the uncertainty in water cycle components in weather and climatic predictions by improving models, data assimilation systems, and data-model integration.
    d) promote studies applying weather and climatic information for efficient water management.
2. The United States and Japan should consolidate and prioritize the working group recommendations for workshops by:
    a) finding the proper balance between scientific conferences and workshops;
    b) holding an informal evening meeting at the IUGG in Sapporo, July 2003, to discuss some of the issues raised in the working group reports;
    c) beginning to plan a major international workshop on the modeling of anthropogenic impacts on regional and global water cycles (Famiglietti and Takeuchi); and
    d) developing plans for an international Workshop on "Global Water Cycles" (Koike, Miller (Norman), and Lawford)
3. Information on exchange programs in the United States and Japan should be consolidated and made available to scientists in both countries.
4. Demonstration projects/studies should be initiated to illustrate the value of enhanced observations and improved predictions for water management decisions.
5. The possibility for a joint U.S.-Japan news release from this meeting should be explored. The news release should emphasize that, "We, scientists, recognize the study of water cycles on global scale is the critical issue to develop the sustainability in society, namely sustainability development but not sustainable development."
6. Commitment meeting(s) should be considered for the United States and Japan to ensure that each country makes a substantive and meaningful commitment to support water cycle and related research, including national water cycle initiatives.
7. Core recommendations arising from this meeting should be monitored as a part of the U.S.-Japan meetings through the CCSP/ USGCRP and the Japanese "Global Water Cycle Variation Initiatives." In addition, the "water cycle" topic should be included on the regular agenda of the U.S.-Japan Liaison Group on Geosciences and Environment.

WORKING GROUP REPORTS

Working Group 1
Long-term Climate and Water Cycle Variability and Change

Co-chairs: Jim Shuttleworth and Tetsuo Ohata (Co-chairs)

Participants: Toshiya Aramaki, University of Tokyo
Mike Bosilovich, Data Assimilation Office, NASA
Seita Emori, FRSGC
Efi Foufoula-Georgiou, University of Minnesota
Haruyasu Nagai, Japan Atomic Energy Research Institute
Tadahiro Hayasaka, Research Institute for Humanity and Nature
Akihiko Ito, FRSGC
Rick Lawford, GAPP Program Manager
Dennis Lettenmaier, University of Washington
Eric Wood, Princeton University

Using the reviews in this subject area given (with focus on meteorological variables) by the 2001 IPCC report [see http://www.grida.no/climate/ipcc_tar/wg1/338.htm] and (with greater focus on hydrological variables) by Professor Lettenmaier at this workshop as the basis for discussion, WG1 assessed what is known and what is unknown on this topic and identified the following gaps in understanding that merit the joint attention of U.S. and Japanese researchers.

Research Gaps

- Definition of metrics to define acceleration in the global water cycle, acknowledging societal relevance.
- Provision of better understanding of the role of the water cycle in stabilizing global climate and in stimulating abrupt changes therein, recognizing the need to explore the possible non-linear sensitivity of changes in runoff to changes precipitation.
- Development of data sets and techniques to allow creation of inventories in the water cycle.
- Greater research interest in high-latitude/cold climate hydrometeorological issues and, in particular, provision of relevant satellite observations and the rescue of existing long-term *in situ* data.
- Fostering of stronger coupling of research into the carbon and the water cycle both in terms of better coordination and collocation of observations and improved simultaneous modeling of transfer processes.
- Quantification of reliability of models' capabilities to predict variability in the global water cycle, including variables and attributes with societal relevance.
- Better definition of the observational requirements and methodologies needed to document long-term variability in the water cycle, with focus of the possibility of finding ways to use the extensive spatial coverage of satellite observations to compensate for their limited duration relative to long-term change.

Recommendations

After detailed discussion of these research gaps, the following recommendations were made.

(a) Identifying Acceleration of the Global Water Cycle

The working group recognized that efforts to identify long-term acceleration of the global water cycle are presently frustrated by the lack of definition of appropriate metrics to quantify such acceleration. They recognized, moreover, that there is currently inadequate understanding of how existing/upcoming observations, including long-term *in situ* observations, medium-term reanalysis data sets that extend backwards before the satellite era, and data from short-term satellite missions (such as the Global Precipitation Mission) can best be used to identify acceleration.

Recommendation: Convene a working group/workshop leading to a white paper to define a strategy for detection of acceleration/intensification of the global water cycle, which includes the definition of appropriate metrics and specification of how different types of data, including *in situ* data, reanalyzed data sets, and short-term satellite observations, can best be used. (Responsibility: U.S.: Bosilovich, Roads, and Foufoula; Japan: Oki and Koike).

(b) Understanding the role of the water cycle in stabilizing global climate and/or initiating abrupt climate change

Because research into the global water cycle is comparatively new, there is as yet no clear understanding of the role of the water cycle in determining the rate of change in global and regional climate, either possibly by stabilizing climate, on the one hand, or by initiating rapid climate change, on the other. The working group recognized the need for U.S. and Japan to take a lead in identifying/documenting current understanding in this important area of interest as an aid to the development of their respective emerging research initiatives into the global water cycle and, as a first step, recommends defining the terms of reference for such a review.

Recommendation: Specify the terms of reference for a review of present understanding of how and if the water cycle influences the rate of change in global and regional climate (Responsibility: U.S.: Lawford; Japan: Hayasaka).

(c) Inventory of the Global Water Cycle:

Providing an inventory of the storage and flux of carbon in the Earth system is an important goal of research into the global carbon cycle. Recognizing that water is a commodity whose availability and movement directly impacts human and ecological welfare, the working group considered that it is at least as important to provide the basis of an inventory of water in the Earth system and acknowledged that the availability of relevant data sets was presently the primary inhibition on progress in this area. They recommended that the U.S. and Japan take the lead in specifying the nature of the data required.

Recommendation: Specify the terms of reference for the development of data sets relevant for inventory of the stores and fluxes of the water balance at the continental and sub-continental scales. (Responsibility: U.S.: Lettenmaier and Wood; Japan Oki and Takeuchi)

(d) High Latitude Hydrometeorology

The working group considered there is under-recognition of the importance of frozen precipitation in the global water cycle and that the limited availability of relevant *in situ* and satellite observations are an important constraint on progress in this respect. Such under-recognition was reflected in the participation of this workshop. There is opportunity for

Japanese and U.S. scientists to work together to redress the data shortfall in this area by seeking to acquire and then protect unrecognized long-term data records from countries where data exist in other than digital forms, and by enhancing the capability of proposed satellite systems, such as GPM, to provide data on frozen precipitation.

Recommendation: Organize a workshop focused on defining data needs for high latitude water cycle studies. (Responsibility: U.S.: Barry; Japan Ohata)

Working Group 2
Prediction of Water Variability on Monthly, Seasonal, and Annual Time Scales

Co-chairs: Akio Kitoh and Jagadish Shukla

Participants: Roni Avissar, Richard Carbone, Jay Famiglietti, Masahide Kimoto, Akio Kitoh, Toshio Koike, Koichiro Kuraji, Norman Miller, Kenji Nakamura, John Roads, Takehiko Satomura, John Schaake, Zubin Zeng,

Background

There are several ongoing international activities involving long-range (monthly to annual) predictions of the water cycle in which scientists from the United States and Japan play major roles. These include the Global Energy and Water-cycle Experiment (GEWEX), the new World Climate Research Project (WCRP) Coordinated Enhanced Observing Period (CEOP), and World Weather Research Program (WWRP), etc.

Collaboration work in GEWEX includes several subjects:

- Global Precipitation Climatology Project (GPCP), which includes TRMM, a joint Japan/US effort to develop global precipitation products on daily to monthly time scales;
- Global Hydrometeorology Project (GHP), which includes substantial participation by the United States;
- GAPP and GAME continental scale experiments. A major goal of GHP is to develop integrated seasonal prediction efforts, which incorporate accurate representations of the atmosphere and land hydrologic cycles;
- Global Soil Wetness Project (GSWP) which is designed to develop the best estimate for global soil moisture;
- GEWEX Cloud Systems Study (GCSS) to develop cloud resolving models that will become the basis for the next generation cloud parameterizations;
- International Satellite Comparison Project (ISSCP); and
- International Satellite Land Surface Comparison Project (ISLSCP).

CEOP is a coordinated international experiment initiated by GEWEX and coordinated by WCRP to develop a pilot global hydrometeorological data set, which can be used to enhance understanding of global water and energy budgets as well as monsoon characteristics, which should lead to increased seasonal predictions. The CEOP data set will include satellite measurements at 41 international reference sites, which also have detailed in situ measurements (almost all long-term global tower sites are included). These observations will be augmented by detailed Model Output Location Time Series (MOLTS) at each of the reference sites, as well as more extensive global gridded output. These global measurements will be augmented by regional output, pertinent to the GEWEX CSEs.

World Weather Research Program (WWRP)

The WWRP is a major programme of international research under the auspices of the WMO Commission on Atmospheric Sciences. Some of its activities are conducted jointly with the WGNE (see below). Ten active or developing projects are in progress ranging from non-dynamical nowcasting of weather to extended range and intra-seasonal predictions of precipitation. Two projects are of especially high relevance to U.S.-Japan collaboration: THORPEX and Warm Season QPF/flooding Initiative.

THORPEX (joint with WGNE) is a global atmospheric research programme, much in the spirit of GARP, that seeks to explore the limits of predictability in relation to initial and boundary conditions analyzed from an adaptive global observing system of the future; improved model representations of physical processes; and advanced data assimilation techniques. Essentially all of the major NWP centers, including JMA, NCEP and ECMWF are involved. Current agreements call for global high resolution "nature runs" on which to base subsequent predictability studies. Experimentally, Asia and the western N. Pacific will be a regional focus of THORPEX to explore the impact of adaptive satellite and in situ observing techniques.

The Warm Season QPF/Flood initiative is at a formative stage. Dynamical Climatology studies are in progress in North America (Carbone and Arkin); Australia (Keenan); China (Wang and Chen); Africa and Europe (Brozkova and Levizzani). Carbone is the lead U.S. scientist and Chair of the international working group. Japan's Baiu/Mei-Yu heavy rainfall is central to this study and Japanese-American collaboration is highly desired for the region in the lee of the Tibetan Plateau in the Mei-Yu/Baiu season. Convective System-Resolving Model (CSRM) simulations, regional in scale and seasonal in duration are needed over East Asia and North America.

The Working Group on Numerical Experimentation (WGNE) is an established group using numerical models on a wide variety of time scales. WGNE projects also include the Atmospheric Model Intercomparison Project (AMIP), Seasonal forecasting Model Intercomparison Project (SMIP)

Predictability of seasonal variability in the water cycle (middle and high latitude)

There are a number of research areas that need improvements for quantifying seasonal predictions. Determining land surface initial conditions and teleconnected global processes, linking atmospheric, oceanic, and land-surface processes with lagged responses, and how their interrelationships modify seasonal variations may be viewed as general needs for improvement.

Summertime continental precipitation needs improvements in observations and models. Precipitation in cloud-resolving models need to be further evaluated against observations. Observations that include satellite-derived data (e.g. GPM, TRMM) and surface gage stations are required as part of a more comprehensive observing network that will provide a more comprehensive model validation. Researching regions affected by orographically forced precipitation (e.g. Tibetan Plateau, Rocky Mountains, Sierra Nevada Mountains) is an area of joint Japan-U.S. collaboration.

Land-surface soil moisture evolution and its impacts on atmospheric flux exchange is poorly predicted due to lack of sufficient observations. New satellite-derived data from the AMSR has approximately a 50-70km footprint, is unable to penetrate soil depths beyond a skin layer, and cannot resolve soil moisture under canopies. The Grace measurement satellite is able to measure large area total deep water fluctuations, but cannot provide any fine horizontal or vertical information. Field measurements are mostly limited to small scale study areas and are difficult to upscale and apply to numerical models for predicting soil moisture evolution. Data assimilation of the above satellite-derived information combined with sparse observations and new spatio-temporal aggregation schemes will allow for improvements in land-surface initial conditions and the predictability of soil moisture, snow water equivalent, and surface fluxes. New algorithms that combine this information can be developed to generate time-evolving soil moisture profiles with depth.

There is a need to build upon existing intensive observing programs by designing a capability to understand the ocean and atmosphere low-to-high frequency teleconnected systems that influence precipitation, surface processes, and their feedbacks. Coordinate joint U.S.-Japan research, along with other international programs, will advance our understanding and provide a framework for the design of next generation seasonal predictions that capture feedback mechanisms and new observations.

Satellite Data and Assimilation

In order to define initial conditions and land surface states for seasonal and longer time scales, a description of vegetation, soil wetness, and snow coverage is required. Further, assimilation of precipitation may enhance predictability. Current U. S. and Japanese sensors will have the capability to provide these data either for initialization or routine assimilation.

Visible and near-infrared sensors (MODIS, GLI, AVHRR) can provide LAI, snow areal extent and surface temperature. Infrared sounders (AIRS, TOVS) can provide water vapor and temperature profiles in the atmosphere over land and ocean under cloud-free conditions. Microwave sounders (AMSU-A, AMSU-B) can monitor these profiles only over the ocean, but for all weather conditions. Microwave radiometers (AMSR, AMSR-E, TMI, SSM/I) can provide surface moisture content, snow water equivalent, vegetation water content, and precipitation. Precipitation radar (PR) can provide the profile of precipitation. GRACE will provide estimates of water storage changes on land.

Limitations in the representativeness and the spatial-temporal coverage of the available products (for example, in soil moisture profiles, estimation of vegetation and snow characteristics) and physical consistency with numerical models, require continued collaboration between U. S and Japanese scientists on assimilation schemes, in addition to retrieval algorithms, in order to fully exploit the potential of remotely sensed data for improved predictability. Optimal combination of in situ data with satellite observations also an important component in these efforts.

Model Improvements and Applications

In long-range prediction (monthly to seasonal), boundary conditions and model physics assume greater importance than in short range forecasts. Among the model physics the representation of clouds is of primary of importance. Convection parameterizations are known to be deficient in the representation of convection in forecast models at all ranges of prediction. Such parameterizations fail to account for the capacity of convection to dynamically organize up to 1000 times the scale of its original elements. The mesoscale dynamics is influenced strongly by physical processes such as: aerosol, cloud, and precipitation microphysics, heating and moistening of the free troposphere, diabatic cooling and the representation of downdrafts, land-surface initiation or triggering of free convection, moisture flux convergence driven by elevated heat sources and gravity-inertia oscillations, heterogeneous environments created by height and areas of clouds associated with convection, and vertical redistribution of horizontal momentum.

It is recognized that there is a stochastic component of convective lifecycles at the very short range, governed by highly non-linear dynamics, and not specifically predictable beyond two or three convective overturning times. The concept of equilibirum on larger scales of prediction applies to regional-seasonal periods such as those within or influenced by monsoonal circulations as observed in Asia and North America. It is also recognized that episodes of convection over tropical-oceanic and many continental regions exhibit sustained organization and coherency on nearly continental scales and may be amenable to skillful intra-seasonal and seasonal predictions.

Such skillful predictions rely on appropriate parameterizations of convection, representation of mesoscale convective systems and the coherent regeneration of these. Skillful predictions also rely heavily on the dependence on larger scale forcing and boundary forcing that must be represented adequately.

Improved fluxes of various physical variables are also needed. The representation of fluxes in stable PBLs must be improved. The moist PBL is also very difficult to represent along with other processes including, cloud topped PBL, cloud development and dissipation related to entrainment from the free troposphere. In sloping and complex terrain special considerations come into play with respect to mixing, and mechanical turbulence generation processes. Observations from GAME, CASES, and extensions of these should guide improved knowledge of model physics and contribute to the development of adequate parameterizations. Also, the same observational data may be used to compare performance of various models in the United States and Japan. This will help employ mesoscale and microscale models in climate research.

A hierarchal approach to the use of models is required, from CSRMs to GCMs. This includes the development of methodolgies for super-parameterization, adaptive grids and one way and two way nesting. A definitive continentel/seasonal-scale CSRM experiment should be conducted for conditions representative of around Tibetan Plateau in rainy season and for North America in mid-summer (July). This experiment would define the appropriate path toward super-parameterization in global climate models of the future. In this regard, validation observations in support of the simulations can make effective use of systematic observations over the United States, Tibetan Plateau, and GAME areas (Siberia to the tropics). Examples of systematic observations include TRMM-GPM, geostationary satellites, DOE ARM and US WSR-88D radar network. The only computational facility capable of CSRM-regional-seasonal simulations is Japan's Earth Simulator and thus could form the basis for a U.S.-Japan collaboration of great significance to prediction of precipitation within the warm season water cycle.

Extreme Events

Hydrologic extremes can be defined on various time scales. At the seasonal time scales, extremes include highly abnormal wet regimes and highly abnormal dry regimes, which are manifested in characteristics of the land surface, especially in the case of drought. There is potential skill in developing these seasonal anomalies, especially if the land surface feedbacks are included in seasonal prediction models. At shorter time scales, abnormal wet episodes result in flood events, which cannot be predicted in detail (timing, duration, magnitude) at seasonal time scales. Changes in the seasonal mean anomaly may be related to changes in the distribution functions, which should allow at least indication of potential extremes. For example ENSO predictions have been used to alert policy makers for potential flood events.

Influence of Human Activities on Climate

The question of the influence of human activities such as land cover/land use change, irrigation, groundwater withdrawal and reservoirs affect on regional climate variability and seasonal predictability is of great social relevance.

However, this problem has not been addressed in the systematic way. In fact this is because of adequate data. Global land cover data are available from AVHRR and MODIS. Land use data are available over individual regions and may be available globally in the near future. Irrigation data may be available based on various field surveys but is not available to global modelers yet. Groundwater withdrawal has been estimated over some region of the world. Geographic locations of reservoirs are available but the additional information on each reservoir is still unavailable. At present, only land cover data and vegetation data (such as fractional vegetation cover and leaf area index) are used in global and regional models.

If irrigation and land use data are available, they can be directly used by current land surface models. However, land surface models need to be further improved in order to make use of groundwater withdrawal and reservoir data. Based on this analysis, for the near term, we should focus on developing the global data sets of irrigation and land use, and incorporate them into land surface models. For the long term, a comprehensive hydro-environmental model needs to be developed that can realistically treat groundwater withdrawal and reservoir as part of the overall water movements over lands.

Working Group 3
Applications of Climate Information to the Water Resource Sector

Co-Chairs: Ruby Leung, Kaoru Takara

Participants: Allen Bradley, Shannon Cunniff, Konstantine Georgakakos, Harvey Hill, Hiroyuki Kawashima, Takao Masumoto, Dave Mathews, Ryohji Ohba, Taikan Oki, Michael Sale, Soroosh Sorooshian, Kuniyoshi Takeuchi,

Summary of discussion

During the first day, WG3 started the discussion with brief introductions by the co-chairs. The participants then introduced themselves and their research interests. Examples of work being done by the working group members include research on the effects of climate change on water resources, hydrologic and land surface modeling, application of remote sensing to hydrology, regional climate modeling, ecology and biogeography, economic development and water resources issues in northern China, flow modeling in low lying areas, study of water issues of the Mekong River, integrating climate information in resource decision making, assessing impacts of climate variability and change on multiuse allocation and reallocation in complex reservoir systems, and effects of social changes on balance in water supply and demand. It was noted that Japan's interests are more closely related to the effects of global warming on water resources while U.S. scientists are studying both the use of seasonal forecasts and climate change information in water management. Members then collectively reviewed the state of knowledge in the field by listing different types of climate information, water applications, and end users that are relevant for the discussion. Each member was then asked to develop a few water application priorities that are of mutual interests with high impacts and leverage on existing programs. Our goal was to develop a few recommendations for collaborative work that can be moved forward.

During the second day, each member of WG3 provided a short list of water application priorities for discussion. These include:

- Prediction of snowmelt/runoff in topographically diverse area;
- Quantification of uncertainty of seasonal forecasts;
- Improvement in precipitation modeling and forecasts for water resource management;
- Development of tools that facilitate the use of probabilistic forecasts in decision-making and policy planning;
- Development of methods for adaptive management in a changing (non-stationary) climate;
- Prediction of water demand using climate information;
- Management of extreme events and disaster control;
- Study of water markets and water trading among sectors and linkage to climate;
- Development of decision support tools that integrate fundamental issues of water management;
- Study of the use of seasonal predictions in developing countries that rely on seasonal precipitation for agriculture (e.g, Thailand);
- Water issues in semi-arid basins such as the Yellow River and semi-arid United States; and
- Socio-economic analyses of vulnerability to climate variability and change

Based on the above list, a set of focused research was developed for potential U.S.-Japan collaboration. This includes:

Recommendation #1

To perform demonstration project(s) bringing together investigators to work on an integrated set of issues related to the linkage of climate information and water management and planning, with participation of end users. Study regions or river basins will be selected based on mutual interest, leverage on existing programs, and coordination with other working groups. The themes of the demonstration projects will be the use of climate information (climate change and climate/weather forecasts) at a range of time scales for effective infrastructure and policy planning, effective management of water resources, and effective emergency planning, management, and response.

Research questions that need to be addressed include:

- Characterization of uncertainty associated with climate forecasts, streamflow forecasts, extreme events, and demand and investigation of methods for bias adjustment and downscaling associated with the use of climate information.
- Develop methods to incorporate uncertainty in decision and management. Examples include decision support system, effective use of uncertainty in managing risks such as extreme floods and droughts, adaptive management, and assessing the value of tradeoffs among competing water uses.

Recommendation #2

- To perform socio-economic analyses of vulnerability to climate variability and change. This includes analyses of environmental issues such as surface and groundwater water quality and ecosystem sustainability (e.g., riparian restoration), and identification of the temporal and spatial scales of vulnerability.

- Study the potential economic welfare implications of improved use of climate information on domestic and international trade. This includes studying the transfer of water and energy, food and agriculture, and labor implications.

Actions:

We propose a workshop to be attended by members of WG3 and potential collaborators to follow up on the two recommendations. For the first recommendation, basins or regions for the demonstration project(s) will be selected after reviewing recommendations from other working groups and on-going programs. Workshop participants will initiate planning of the demonstration project(s) and determine research focus and data requirement that are specific to the basins or regions chosen. For the second recommendation, workshop participants will aim at refining the objectives and develop outlines for projects that can address the issues and define achievable outcomes.

Working Group 4
Observational Programs

Co-Chairs: Eric Wood and Toshio Koike

Participants: Roni Avissar, Efi Foufoula-Georgiou, Konstantine Georgakakos, Tadahiro Hayasaka, Koichiro Kuraji, Rick Lawford, Kenji Nakamura, Tetsuo Ohata, Takehiko Satomura, John Schaake, Jagidish Shukla

Recommendations

1) For Japan and U.S. to provide international leadership in global water cycle observations in support of water cycle research through activities that include joint programs in water cycle observations (validation sites and analysis) and the establishment of data integration centers.

This recommendation builds upon recent international agreements (WSSD parag. 27: IGOS water cycle theme; submitted UNFCCC/SBSTA/COP agreements.)

Specifically, the working group recommends:

- *Data Integration Centers*. Establishment of collaborative water cycle data integration centers. Archiving, integration and data mining efforts. (Collaboration between UCAR, NASDA and NASA water cycle data center which is proposed.)

- *Reference and Validation Sites*. Establishment of a water cycle observation complex based on U.S.-Japan collaboration for long-range, medium- and short-term observations. The issues may include the establishment and management of hydrologic/ecologic super stations or reference sites globally, coverage for major climatic zones, recognizing the special high latitudes needs; and the need for historical data, perhaps requiring data rescue.

    - Design and establish an international ground-based observational network (space-time data tradeoffs; observational targeting, experimental catchments, etc.)
    - Needs for a comprehensive and continuous satellite observing strategy, including archiving and accessibility.
    - Needs for international administrative expertise and governmental cooperation from all countries to apply the newly integrated water cycle information.

Action Item: White Paper on reference sites. (Shaake, Lettenmaier, Kuraji, Nakamura, Ohata)

2) Japan and the U.S. jointly organize a major scientific workshop organized around the "*Application of observing systems to document the global water cycle.*"

Action Item: Write a short proposal for such a workshop and present it to NASA and NASDA (and other interested US and Japanese agencies) for their support and organization.
Possible date for the workshop: summer 2004.
(Japan: Nakamura, Koike/U.S.: Wood, Shuttleworth, Eric Smith)

The workshop would be organized around major science questions and programmatic issues centered on the water cycle. For example:

- How do we use data to identify acceleration in the water cycle?
- Use of satellite data for data assimilation; identification of observational targeting for seasonal prediction.

Format:

- 3-5 days
- Attractive location
- Engage WCRP activities (GEWEX, CLIVAR, CliC, etc.)
- Organized by the United States and Japan, but explicitly open, with invited international experts.
- Program:
    - 1+ day definition of available observing systems including:
        - satellite systems
        - oceanographic systems
        - re-analysis data sets/ data assimilation
        - historic in-situ data sets
        - surrogate data
    - approximately 3 days: Big science questions, one per day
        - Quantifying acceleration of the global water cycle
        - Documenting variability in monsoon systems
        - Providing data for water resource management and design in poorly gauged areas
- Key people:
    - U.S.: Eric Smith, Lettenmaier, Wood, Ocean observations people, HELP, reanalysis person,
    - Japan: Koike, Nakamura, Takeuchi, Ocean persons, reanalysis persons
    - Invited Experts: ESA, ECMWF

Gaps in observation programs.

Collaboration on the anthropogenic river flows and the anthropogenic effects of the water cycle. It may include possible Japanese participation on U.S. WG that is using altimetry to measure lakes, reservoirs and rivers. Recommend the establishment of a joint U.S.-Japan working group to develop data needs and exchange data sets (Japan: Oki, Takeuchi; US: Lettenmaier, Vorosmarty)

Needs for global observations for weather and seasonal climate predictions

Weather and seasonal climate models need consistent observations of surface states that can only be achieved through a combination of remote sensing and land surface modeling. There is strong support for the measurement of precipitation, soil moisture, snow and frozen ground from space. It is recommended that a small research meeting be convened between US LDAS scientists and Japanese researchers interested in land data assimilation with the purpose of establishing formal collaboration. (Contacts: Oki; Houser/Rodell, Wood)

Improved precipitation measurements from space.

1. Increased collaboration in improving measurement of solid precipitation from space through the GPM; especially joint collaboration with the European GPM radar.

2. Increased collaboration in improving measurement of precipitation from space over the oceans.

3. Improved understanding of the errors from satellite estimated precipitation.

Support of international efforts

Recognition of the joint activities in IGOS for operational and local ground data relevant for water cycle research.

Working Group 5
Model Development

Co-Chairs: John Roads (UCSD)- GEWEX, CEOP, seasonal forecasting; Seita Emori- Frontier Research Center for Global Change- integrated earth system model, IPCC models

Participants: Mike Bosolovich, NASA (data assimilation)
Allen Bradley, University of Iowa- hydrology, quality of information going into models Akihito
Jay Famiglietti, University of California at Irvine- soil moisture and soil water remote sensing
Ito, terrestrial
Masahide Kimoto, GCM development
Akio Kitoh, Meteorological Research Institute- Monsoon, and ENSO
Dennis Lettenmeier, University of Washington- VIC and land surface modeling analysis
Ruby Leung, PNNL- coupling land atmosphere models mesoscale models
Norman Miller, University of Arizona -land surface groundwater
Taikan Oki, Research institute for humanity
Soroosh Sorooshian, GEWEX- hydrologist
Xubin Zeng, University of Arizona- interface process and atmospheric boundary layer

Major modeling Groups

US Groups	Japan Groups
NCEP data assimilation weather forecasts	JMA/MRI Coupled model IPCC runs Regional (cloud resolving)
DAO data assimilation short term climate simulations	Frontier Research Program FRSGC CCSR/NIES coupled model IPCC runs
NCAR IPCC	
GFDL IPCC	

Several associated university groups are working with and somewhat independently of these major modeling centers

International

Working group 5 recognizes several ongoing international activities involving long-range (monthly to annual) predictions of the water cycle in which the United States and Japan play major roles.

GEWEX

a. Global Precipitation Climatology Project (GPCP), which includes TRMM, a joint Japan-U.S. effort to develop global precipitation products on daily to monthly time scales.
b. Global Hydrometeorology Project (GHP), which includes substantial participation by U.S. GAPP and GAME continental scale experiments. A major goal of GHP is to develop integrated models of the water cycle.
c. Global Soil Wetness Project (GWSP): A project to develop the best estimate for global soil moisture.

d. GEWEX Cloud Systems Study (GCSS): A project to develop cloud resolving models that will become the basis for the next generation cloud parameterizations.
e. International Satellite Comparison Project (ISSCP)
f. International Satellite Land Surface Comparison Project (ISLSCP)

CEOP

CEOP is a coordinated international experiment initiated by GEWEX and coordinated by WCRP to develop a pilot global hydrometeorological data set, which can be used to enhance understanding of global water and energy budgets as well as monsoon characteristics, which should lead to increased seasonal predictions. The CEOP data set will include satellite measurements at 41 international reference sites, which also have detailed in situ measurements (almost all long term global tower sites are included). These observations will be augmented by detailed Model Output Location Time Series (MOLTS) at each of the reference sites, as well as more extensive global-gridded output. These global measurements will be augmented by regional output, pertinent to the GEWEX CSEs.

Other

WGNE (Working Group on Numerical Experimentation)

IAEA International Atomic Energy Association

WCRP CLIC/ACSYS cold season processes

IARC, International Arctic Research Center (in Alaska)

Recommendations

1. CEOP

Background

An overarching issue raised in many of the working groups is that deficiencies leading to biases in model data can significantly impact the usefulness of the data in both scientific investigation of climate change and variability and in the applications of the data to societal problems. While this is not a new issue, many discussions have taken place during the workshop on how Japanese and United States scientists could lead or collaborate in improving the current situation. One possible setting to foster this collaboration may be the Coordinated Enhanced Observing Period (CEOP), where United States and Japanese scientists are already working together (along with the international GEWEX community).

CEOP is currently collecting model forecasts and analyses, as well as in-situ and remotely sensed observations. The observing period will be for more than three years. This convergence of many types of data should provide a critical period for global and regional model development and validation. With multiple models, analyses and observations, uncertainties for certain parameters can be quantitatively estimated. While this is only a three-year period (short for climate studies), GCMs could be evaluated by producing climate statistics given appropriate forcing.

Recommendation: Make CEOP a benchmark period for model (global and regional) validation and development and promote interdisciplinary studies to evaluate the impact of model biases on societal decision-making and sub-models (e.g. ground water, water quality etc.).

Action Item:
Encourage American and Japanese participation in CEOP program to not only provide data but also to utilize the data for various scientific studies. Develop independent model intercomparisons over the CEOP time period.

2. Coupled Land-Surface and Groundwater Model Development
(Miller, Sorooshian, Oki)

Management of surface water quality is often complicated by interactions between surface water and groundwater. Traditional Land-Surface Models (LSM) used for numerical weather prediction, climate projection, and as inputs to water management decision support systems, do not treat the lower boundary in a fully process-based fashion. LSMs have evolved from a leaky bucket to more sophisticated land surface water and energy budgets that typically have a so-called basement term to depict the bottom model layer exchange with deeper aquifers. Nevertheless, the LSM lower boundary is often assumed zero flux or the soil moisture content is set to a constant value; an approach that while mass conservative, ignores processes that can alter surface fluxes, runoff, and water quantity and quality. Conversely, models for saturated and unsaturated water flow, while addressing important features such as subsurface heterogeneity and three-dimensional flow, often have overly simplified upper boundary conditions that ignore soil heating, runoff, snow and root-zone uptake.

Recommendation: Joint US-Japan studies of the coupled atmosphere-land-groundwater need to be initiated. Research watersheds, one each in the United States and Japan, need to be identified. These watersheds should be part of a larger set of study basins (e.g. GEWEX, HELP). Regional models would be a useful starting point for global models.

Action Items:
A workshop to determine watersheds to be used as part of these studies and an exchange of scientists to develop new models and datasets

3. Incorporating Natural Isotopes into Climate Models
(Miller, Oki, Sorooshian)

To quantify global water cycle processes, the implementation of natural isotopes as tracers in the atmosphere, land-surface, and ground water are viewed as an advancement in model development. Inclusion of hydrogen and oxygen isotopes as tracers will provide a means for measuring atmospheric flux sources and sinks, land-surface and sub-surface fluxes and the partitioning between old and new water.

Atmospheric water isotope cloud physics packages and land-surface/sub-surface schemes need to be developed in collaboration with the International Atomic Energy Agency and the Global Natural Isotopes in Precipitation Program. Joint research and development among Japan and U.S. modeling groups working through partnered projects, workshops, and scientific exchanges programs will help to bring this about.

Recommendations:
More coordination of sampling and measurement through IAEA.

Action Item:
Develop a U.S.-Japan working group to develop a major 10-year initiative.

4. Land Surface Model Development
(Jay Famiglietti, T. Oki)

An important area for U.S. – Japan collaboration is in the area of incorporating water management practices (e.g. irrigation, reservoir storage) in land surface models. Human manipulation of surface and groundwater likely has significant impacts on regional, and perhaps global climate, and its representation in land surface models has been lacking.

Recommendations: A two-level model development strategy could be pursued. One level could be coarse representation of irrigated lands and reservoir storage in land surface and river transport models. Such a representation will enable important sensitivity studies with regional and global climate models in which Japanese and American scientists could collaborate.

A second level could model these and other aspects of water management (e.g. water transfers) in more detail in offline models. These offline models could be used as "reference" models for the coarser representation in climate models, and could include detailed information such as irrigation scheduling and reservoir operating rules. The offline models would also be critical for downscaling output from global climate change scenarios. Assembling the relevant data sets will require considerable effort and should involve the Japan, the U. S. and other international collaborators. The GAPP applications program for incorporating water management practices into streamflow prediction could provide valuable guidance for how to proceed with this effort.

More generally, both countries could collaborate on the further development of the coupling between land surface and river transport models. The representation of lakes and wetlands along the channel network are a good example. These features impart important storage lags and are a function of both water table dynamics in the land surface model and the morphology of the landscape along the network. Realistic modeling of these storages, which are important to both the water cycle (through evapotranspiration and hydrograph impacts) and biogeochemical cycles (through trace gas fluxes) requires a wholistic approach.

Begin exchange of relevant data sets for irrigation, reservoir storage, water management practices.

Action Item: Workshop between the United States and Japan on water management practices.

5. Model Development Needs Related to Permafrost
(Kitoh and Miller)

Under a warming climate, changes in permafrost will alter both the rate of fresh water input to high latitude oceans and the release of methane from peat land bogs. These two feedback mechanisms may contribute to a thermohaline circulation slowdown and an increase in green house gas absorption, respectively. Land surface models in current climate models include ice phase in soil moisture and represents permafrost processes in a simple fashion. This approach does dynamically handle the complexity of the land surface – subsurface rates of change of multi-phase water movement. A one-dimensional permafrost model needs to be incorporated into land surface models as an advanced model development.

Recommendation: International collaborations with contributions from the United States and Japan are needed. Model development of permafrost processes and the associated biogeochemical processes will be need to be developed as part of advanced land-surface modeling studies and evaluation.

Action Item:
Support for scientific exchange through IARC.

6. Coupling of Water Cycle and Carbon Cycle
(Akihilko Ito and Xubin Zeng)

On the US side, there are separate Carbon Cycle Initiative and Water Cycle Initiative. On the Japanese side, there is the All Japan Carbon Cycle Project, and various water cycle projects funded by various agencies. There are about 30 to 40 land surface parameterization schemes simulating water and energy cycles without considering carbon cycle. There are also many carbon cycle models without careful consideration of the energy and water cycles. The linkage of water and carbon cycles is concurrent photosynthesis and transpiration processes. Most models have in one way or another considered the photosynthesis–conductance relationship, but many other linkages between the water and carbon cycles have not been considered or understood yet. For examples, most of the biophysical land surface models use specified vegetation parameters. In reality, most vegetation parameters, such as rooting depth, albedo, roughness, and water holding capacity, vary with age of the vegetation. For carbon cycle models, in contrast, the water cycle treatment is typically simple (e.g. Sim-CYCLE with only 2-layer).

Recommendation: Recognizing the importance of water and carbon cycles in climate and global change, we recommend having a joint Japan-U.S. workshop of water and carbon cycle modeling. The purpose of this workshop is to: (a) bring water and carbon modelers together; and (b) develop a priority list for joint research in linking water and carbon cycles. The current FLUXNET and to certain degree CEOP in which both Japan and the United States are playing leading roles could provide the necessary datasets for the model evaluation and validation.

Action Item: Ito and Zeng to develop focused workshop

7. River Transport and Thermohaline Circulation (THC)
(Jay Famiglietti)

The global oceanic thermohaline circulation is a main driver of climate on long time scales. The formation of deep water, which forces the THC, is critically sensitive to freshwater inputs from the continents, sea ice, and precipitation. A key area for collaboration is hence the impact of continental freshwater outflows on the THC.

Recommendations: Areas for exploration include the uncertainty in riverine outflow rates from routing models and the need for streamflow observations at high latitudes for validation; the representation of river freezing in river transport models; and the sensitivity of North Atlantic Deep Water formation to ocean model physics and dynamics.

Action Items: Perform simulations with U.S. and Japanese coupled models and interact with ocean measurement programs.

Working Group 6
Assessments of Water Supply and Demand

Co-chairs: Shannon Cunniff, Hiroyuki Kawashima
Participants: Toshiya Aramaki, Susanna Eden, Harvey Hill, Rick Lawford, Takao Masumoto, Dave Matthews, Haruyasu Nagai

Introduction

IFPRI and IWMI have predicted the rapid rise in demand for the world's increasingly scarce water supply.[1] Agriculture needs will continue to complete with industrial and municipal demands. Environmental uses will be stressed and water quality will decline. As water resources degrade, the cost of developing new sources and treating water is increasing.

Climate change will affect both water supply and water demand. As such, knowledge of both the potential and significance of climate change on global and regional shifts in supply and demand will be crucial for development of policies and programs and will likewise be critical for regional and local water resources planning. Understanding the factors affecting demand and patterns of use will enable policy makers to evaluate the most effective options for meeting demands with supplies. The impact of climate change must be integrated with other environmental, technological, social, and economic factors to effectively identify the challenges and evaluate opportunities for averting crisis.

Working Group 6 focused on issues related to enhancing the assessment of water supply and demand and integrating this information with climate change and other factors to enhance informed planning and decision-making regarding strategies to minimize vulnerability and increase flexibility.

Discussion guiding questions included:

- Will there be a world water crisis in 2050 and if so why? What can be done about it?
- How can we assess the implications of water quality effects in water assessments?
- How can the extent and consequences of ground water use be monitored?
- What types of information are needed to monitor the effectiveness of water recycling and conservation programs?
- What are the demands, real withdrawals, and consumption of water resources? How can these variables be monitored/estimated?
- What is the value of global water assessments of supply and demand and how should they be used in policy development and in resolving regional water conflicts? How useful are regional assessments of water supply and demand for these purposes?
- What types of information are needed by operational water resource agencies? What needs to be done to ensure these information needs are met?

[1] Mark W. Rosegrant, Ximing Cai, and Sarah A.Cline. 2002. "Global Water Outlook to 2025: Averting an Impending Crisis." International Food and Policy Research Institute and the International Water Management Institute.

What do we know?

Better predictions or forecasts will increase confidence and allow water managers to more effectively incorporate this new information. Data on water supply, yields, demand, and actual use are inconsistent, making meaningful comparisons and conclusions difficult.

Early collaboration is necessary to build the compatibility necessary for developing the capacity to create sophisticated models necessary for integrating global climate change with the numerous other factors effecting water supply and demand.

To a degree, we know where the potential crises are likely to be based on current conditions and trends.

There will be regional differences in the ability to deal with water stress. In Japan, there will be no water crisis where river systems are well controlled. Where there is a lack of control for irrigation withdrawals in other places in Asia, such as the Mekong, there is a higher likelihood for crisis from competing demands for water. In the United States, population shifts to water stressed regions indicate the need for increased attention to long-term planning and development of incentives to reduce demand and re-align uses. Differing political systems will require different strategies to address issues.

Urbanization and water for food production are the biggest challenges of the next century, especially for developing countries.

Changing life styles, including diet, will place additional demands on land and water well in excess of current demands.

Application of new technologies can help meet demand.

Occurrence of more extreme events such as floods and drought will financially stress countries and could cause temporary and long-term population shifts.

Reducing demand is critical for future water resources planning.

Water resources planning typically considers 25 to 50-year horizons in part to ensure that infrastructure development and institutional change can keep pace with demand. Using the emerging knowledge of climate patterns and climate change is crucial to sound planning.

There are experts in demand estimation as well as water use that need to be consulted to further develop these ideas.

Important Research Gaps

There are compelling needs to:

- Identify areas especially vulnerable to water resource crisis;
- Gather data on water demand and supply assessments that fits standard protocols and can thereby build confidence in data for all regions;
- Enhance utility and confidence in meaningful and useful models;
- Integrate knowledge of weather, climate events, decadal oscillations, and climate change with river operations and planning decision support tools;

- Understand the impacts of climate change on supply, demand and quality of water resources;
- Ascertain the other potentially significant factors that will effect supply and demand and integrate climate change together with these factors to develop future scenarios that can be used to target research toward the most significant issues and areas;
- Integrate multiple scientific disciplines (e.g., climatology, hydrology, ecology, agronomy, economics, social sciences, and engineering) and link science with decision-making; and,
- Coordinate data gathering and data analysis capacity building pertinent to global water supply and demand issues.

Accurately forecasting demand and consumption will require more accurate estimates of cropping patterns (types and acreage), type of irrigation, if any, or the potential to use alternative irrigation methods. Similarly, trends in agricultural research need to be accounted for to consider the effects of changing yields, the advent of expanded use of drought and salt tolerant species, and improvements in irrigation technologies, to name just a few factors. Shifts in economic status, life styles and diet will also affect demand and consumption. Expansion of new water supply technologies, such as water recycling and desalination, could significantly alter water stresses. Ground water conditions, as well as the potential for aquifer storage and retrieval and strategies that more effectively and sustainably integrate groundwater and surface water management, need to be considered. These are only a few of the potentially significant factors whose evaluation and integration are needed to more accurately predict global, regional, and local water yields, water demands and actual consumptive use. Global climate change has the potential to affect many of these factors beyond simply the quantity and timing of water supply. For example, climate change impacts consumptive use by crops, evaporation rates of water storage and delivery infrastructure, and water quality. These factors need to be an integral part of analyses to begin to construct meaningful planning scenarios that can guide decision making at multiple scales. Scenario development can help to identify "no regret" decisions on investments in technologies or actions, e.g., efficient irrigation system. Water supply and demand assessment would support scenario development.

In developed countries, such as the United States and Japan, where water control and supply infrastructure is well established, modeling emphasizes decision support tools. Demand management is, however, becoming of increased importance in the United States. In developing countries, where control of supply is not as advanced, demand management appears to be more important. Transitional countries in the process of developing water supply infrastructure, such as China, may benefit from tools assisting both supply and demand.

Scale (global, regional, local) will be important in data acquisition, tool development, and interpretation of results. Enhanced understanding of water supply and demand is needed at all scales, local to global.

Areas of common research interest

There exist common interests among researchers in Japan and the United States due, in part, to the similar level of development of water resources infrastructure. Development and testing of hypotheses in a basin in Japan and in the United States will help to create a more robust model. Analysis of a basin in an emerging country would yield additional information and allow expansion of model applications.

Recommendations

- Convene a workshop to develop a detailed proposal for a process to accomplish the integration of knowledge of weather, climate events, climate change, and eventually decadal oscillations with river operations and planning decision support tools.

  First steps should include identification of types of data needed, existing tools, selection of study areas based on the intersection of data capacity and vulnerability to climate change enhanced shifts in water resources and agriculture. Sites in Japan and the United States are suggested along with the option of a study area in an emerging nation. (Hill, Masumoto, Matthews, Yoshitani)

- Develop a proposal for embarking on a long-range scenario development that builds on IFPRI (2002) scenarios and incorporates climate change and evaluates known and unknown but possible shifts in social, economic and technological areas. Scenario development would help policy makers and international deliberating bodies target research, anticipate cross-cutting needs, and otherwise develop flexible plans for responding to actual change. Develop and implement a strategy to build support for this effort. Possible interest groups or sponsors could be UNESCO and IPPC. (Cunniff, Kawashima, Lawford)

- Develop a white paper on demand estimation that addresses data sources, techniques, and tools as well as identifies factors affecting demand, with an aim toward developing a capability for enhancing demand estimation and prediction useful to assist long-term policy making. The white paper would inventory the state of data and tools (inventory) and identify research needs and set the stage for a workshop to fill gaps and integrate data (see below). (Aramaki, Eden, Hill, Oki, Vorosmarty)

- Convene a workshop focusing on determining additional activities necessary to develop means to integrate data that will identify sources of stress and flexibility for water resources management. (Lawford)

- Assess the need for an institution to advocate for and provide international leadership on water and water assessment. Its focus would be on integrating the sciences as well as integrating science into decision-making to facilitate meaningful collection, interpretation, and timely use of data. (Kawashima, Lawford,)

APPENDICES

Appendix A: Program Agenda

Agenda
10th U.S.-Japan Workshop on Global Change
Climate and Water

January 15, Wednesday

7:45 Shuttle to Beckman Center – *Meet at Hyatt Newporter Front Drive*

8:00-9:00 Breakfast - *Beckman Center Dining Room*

9:00-9:30 Registration-*Check in Tables Near Auditorium*

9:30-9:45 Plenary Session I –*Auditorium*

Welcoming Address

Lou Brown, Senior Staff Associate for International Science Affairs, Directorate for Geosciences, National Science Foundation

9:45-10:15 Co-convenors' Addresses

Richard Lawford, GAPP Program Manager and Director of the Global Water Cycle Program Office

Taikan Oki, Associate Professor, Research Institute for Humanity and Nature

10:15-10:45 Keynote Addresses

Masahide Kimoto, CCSR, University of Tokyo
Prediction of Climate and Water Cycle Variability on Monthly, Seasonal and Annual Time Scales

10:45-11:00 Break – *Refreshments Available in Atrium*

11:00-12:30 Keynote Addresses –*Auditorium*

Soroosh Sorooshian, University of Arizona
Helping Water Resource Management Face Global Change Through Hydroclimatic Research: Pitfalls and Prospects

Kunioshi Takeuchi, Yamanashi University
Assessments of Water Supply and Demand

12:30-1:30 Lunch – *Beckman Center Dining Room*
(Set up for Poster Session I in Atrium)

1:30-2:30 Poster Overviews (3 minutes each) - *Auditorium*
(See speaker schedule at end of agenda)

2:30-3:30 Poster Session I - *Beckman Center Atrium – Refreshments available*
Topics 1-3

3:30-4:00 Keynote Address – *Auditorium*
Dennis Lettenmaier, University of Washington
Long-term Climate and Water Cycle Variability and Change

4:00-4:10 Plenary Session II –*Auditorium*
Introduction of Working Groups
Charge to Working Groups

4:10-5:30 Working Group Sessions (1-3) - *Board Rm, Laguna Rm, Crystal Rm*
Review of state of the research
Discussion

5:30-7:00 Welcome Reception – *Atrium (Cash bar)*

7:15 pm Shuttle bus departs for Hyatt Newporter

January 16, Thursday

7:15 Shuttle to Beckman Center - *Hyatt Newporter Front Drive*

7:30-8:00 Breakfast – *Beckman Center Dining Room*

8:00-10:30 Working Group Sessions (WG 1-3)
Board Rm, Laguna Rm, Crystal Rm
Discussion
Draft Recommendation

10:30-10:45 Break – *Refreshments Available*

10:45-11:45 Working Group Sessions (WG 1-3)
Wrap up and summary

11:45-12:45 Plenary Session III - *Auditorium*
Working Group Chair Reports (15 minutes each)
Discussion

12:45-2:00 Lunch – *Beckman Center Dining Room (set up for poster session II in Atrium)*

2:00-3:00 Plenary Session IV - *Auditorium*

Keynote address

Kenji Nakamura, HyARC, Nagoya University

Japan;s Progress in the Blobal Precipitation Measurement (GPM)

Roni Avissar, Duke University

Development of a New Generation of Earth System Models

3:00-4:00 Poster Overviews (3 minutes each) - *Auditorium*

(See speaker schedule at end of agenda)

4:00-5:30 Poster Session II – Atrium – *Refreshments available in Atrium*

Topics 4-6

5:45pm Shuttle bus departs for Hyatt Newporter

January 17, Friday

7:15 Shuttle to Beckman Center - *Hyatt Newporter Front Drive*

7:30-8:00 Breakfast – *Beckman Center Dining room*

8:00-10:30 Working Group Sessions (WG 4-6)

Board Rm, Laguna Rm, Crystal Rm

Review of state of the research

Discussion

10:30-10:45 Break – *Refreshments available in Atrium*

10:45-12:00 Working Group Sessions (WG 4-6)

Draft Recommendations

Wrap up and Summary

12:00-1:00 Plenary Session V - *Auditorium*

Working Group Chair Reports (15 minutes each)

Discussion

1:00-2:00 Lunch - *Dining Room*

(Meeting of co-convenor's and working group chairs)

2:00-3:15 Co-convenor's Report and Drafting of Workshop Report and Recommendations (working session) - *Auditorium*

3:15-3:30 Closing Remarks - *Auditorium*

4:00pm Shuttle bus departs for Hyatt Newporter

Appendix B: Participants

10th U.S. – Japan Workshop on Global Change

U.S. Delegation Participant Contact List

(Alphbetically)

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Appendix C: Keynote Abstracts

(*In order in which they were presented*)

Introductory Remarks

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This talk provides a welcome and overview for participants in the bilateral meeting between the US and Japanese hydrometeorological communities and outlines the possibilities for this meeting. This meeting on climate and water is very timely for both our countries. In Japan, considerable effort has been invested in developing a plan for the study of variability in the water cycle. The Japanese government has attached a significant priority to topics related to water. In the United States, the USGCRP (United States Global Change Research Program) asked Prof. George Hornberger to form a study group and to develop a report of critical science issues. As a result of this effort an Interagency Working Group is now considering approaches to addressing these priorities and incorporating them into the plans for a US Climate Change Science Program (CCSP). The scientific issues facing our communities involve determining whether or not climate change will accelerate the water cycle; developing a capability to predict water cycle variability on seasonal time scales; and understanding the linkages between water cycle variability and variability in major biogeochemical cycles such as carbon and nitrogen cycles. In addition, another interagency group is examining the research needed to support water resource applications. Both of these perspectives are represented at this workshop and recommendations from this workshop will be taken back to these working groups to consider.

The workshop is also timely because extensive infrastructure is now available for advancing water cycle science. Both the GEWEX Asian Monsoon Experiment (GAME) and GEWEX Americas Prediction Project (GAPP)/ GEWEX Continental-scale International Project (GCIP) carried out under the auspices of the Global Energy and Water Cycle Experiment (GEWEX) and the World Climate Research Programme (WCRP) have yielded unique data sets and observational programs that are continuing under the Coordinated Enhanced Observing Period. Much of the progress in Japan has come through the formation of large institutions, such as the Frontier program, that draw together the best expertise in the university and government sectors to address scientific problems. Also, the ability to mount large observational programs and implement major computing advances has been accelerated through these initiatives. In the USA, where the atmospheric sciences have been well served by the National Centers for Atmospheric Research (NCAR) for a number of years, efforts on now underway to develop some new facilities in the area of hydrology through the CUASHI. In addition, our two countries manage two of the three world's largest space programs. The capability to observe from space has never been greater with the recent launches of satellites such as AMSR, Terra, Aqua, etc. Given the major science questions that face our communities it is very timely to consider ways in which our two countries can work together to mobilize our scientific capabilities.

The US and Japan both play important roles in organizations such as the WCRP and UNESCO. The recent decision by the USA to join UNSESCO will provide another framework for collaboration on water and climate issues. Within the IGOS-Partnership, the US (through the WCRP) and Japan are playing leading roles in developing an IGOS Water Cycle theme. Japan has also played a strong role in UN initiatives such as the World Summit on Sustainable Development (WSSD) held in Johannesburg and the Third World Water Forum. Over the next three days we should take this opportunity to strengthen the partnerships and research activities that govern our common interests of these international programs and initiatives.

Research Opportunities in Water Cycles and Climate

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More concerns are paid for water related issues in these days. In the millennium declaration (55.2), which was adopted by the General Assembly of the United Nations in September 2000, it was stated in section 19;

To halve, by the year 2015, the proportion of the world's people whose income is less than one dollar a day and the proportion of people who suffer from hunger and, by the same date, to halve the proportion of people who are unable to reach or to afford safe drinking water.

Similar statement was included in the Plan of Implementation from the World Summit on Sustainable Development held in Johannesburg in August 2002, in article 6 of Chapter II Poverty eradication.

In addition to that, the access to basic sanitation was also focused in article 7. In the WSSD Plan of Implementation, further research and development on water related sciences was urged together with researches on energy technologies, bio-technology, environmental management, marine resources, and sustainable development. All these international vision/action statements aim to alleviate poverty particularly in developing countries.

Under such a movement, what kind of researches can be offered from scientific community in order to contribute to solve the current water related issues and the anticipated ``water crisis'' in the near future in the world?

In preparation for WRAP (Water Resources Application Project) under GEWEX (Global Energy and Water Cycle Experiment) Hydrometeorological Experiments Panel (GHP), these items were identified to answer to the question generally. These are to provide;

- reliable information on
  - past and current global hydrological cycles,
  - near-real time to seasonal prediction on natural variability of climate, such as El Nino and La Nina, and
  - the change in hydrological cycles under climate change conditions, such as global warming,
- quantitative estimate how much water is (and will be) really available for further water withdrawal for human beings, and
- alternative measures to be taken in order to secure the water supply to meet the water demand.

The first three items under the category of ``provide reliable dataset'' can be done by natural scientific approaches, however, the other two should require inter-disciplinary collaboration between natural and social sciences. The planned Joint Water Project by WCRP (World Climate Research Programme), IGBP (International Geosphere-Biosphere Programme), IHDP (International Human Dimensions Programme), and DIVERSITAS (An International Programme of Biodiversity Science) will be an appropriate platform to pursue such a collaborative research (http://www.jointwaterproject.net/).

To provide reliable dataset of past and current global hydrological cycles, continuation of observational network, research and development on new observational measure, and "data rescue" of historical records are important. Satellite remote sensing could be the only hope to provide global coverage of hydro-climatic information, however, ground based network should be held by all means to secure the reliability of global observation. Since there are not a few historical records that are not digitized but covers more than hundred years, database development of these data is also important.

Global offline simulation of LSMs (land surface models) can provide global flux and balances of water, energy, and even more (such as carbon). However, the accuracy of the estimates is subject to the accuracy of LSM itself, forcing data, model parameters, and temporal and spatial scales employed. Therefore the uncertainties associated with the global estimates by LSMs will be examined in the GSWP (Global Soil Wetness Project) under GEWEX/GLASS, Global Land Atmosphere System Study
(http://hydro.iis.u-tokyo.ac.jp/GLASS/Doc/2002/GSWP-2_Edited_B.pdf).

There are many researches to improve providing seasonal prediction of water cycles. It seems widely believed that the improvement in giving boundary conditions over land will improve the accuracy of seasonal prediction of water cycles over land. Usage of better LSMs in GCMs and satellite derived surface conditions, such as soil moisture, may contribute for the improvement, however, how land surface condition matters to the prediction of hydrological cycles over land should also be investigated. For that purpose, the GLACE (Global Land-Atmosphere Coupling Experiment) under GEWEX/GLASS is planned (http://hydro.iis.u-tokyo.ac.jp/GLASS/Doc/2002/glace2002.pdf).

Statistical approach may be useful to give predictions, as well. Even though that could be only for ad-hoc applications, but new insights in tele-connection of hydro-climatology may be found from the sensitivity tests of the statistical models.

The prediction of climate change particularly global warming itself is attracting a lot of attention. Since most of the reliable predictions of hydrological cycles in the future are estimated by GCM simulations, the way to interpret or transform the GCM estimates to water resources assessment is the another key issue. Down-scaling the coarse spatial (and temporal) resolution of GCM estimates is one of the scientific problems, but there are many technical issues such as bias reduction of GCM estimates and the reproductivity of statistical characteristics particularly on precipitation simulated in GCMs. How to extract robust information from GCM predictions on water cycles in the future should be paid more attention.

As for the human dimension side, how to draw the prospect on water demand, withdrawals, and consumption is basically needed. They are generally estimated with the outlook of the future growth of population, economy, etc., but it is very difficult to fully include the impact of innovation in technology and change in policy. Therefore somehow scenarios should be set to assess the future demand in water resources. Even though socio-economic scenarios are used in the projection of future climate in IPCC, most of them do not include the feed back mechanism how water shortage suppress various social activities and economical growth.

There is no guarantee that complex model will provide better results, but interactive modeling on water consists of natural climate system, hydrological cycles, anthropogenic activities such as irrigation, regulation by reservoirs, landuse change, etc., may provide new insights in the global water resources assessments. Virtual water trade, how much domestic water resources are saved by international trade of products, may be incorporated with the modeling of ``real water."

Regional studies should be important for policy making, and it is recommended that information on water demand and water management should also be collected when hydro-climatic regional studies will be taken. Based on the regional studies, science-based decision-making tools should be developed, which can cooperate with the uncertainties included in each component of prediction.

Global studies are also expected to provide useful information for regional studies. In practice, there are many places in the world where global datasets of precipitation, landuse, soil types, etc., are the only sources available for hydro-climatological studies. Therefore the applicabilities of the information on integrated water resources management on local/regional scales will be examined under the Project for Prediction of Ungauged Basins (PUB) of IAHS (International Association of Hydrological Sciences).

This workshop aims to prioritize the relevant research activities on water cycle and climate in US and Japan. However, ensuring research grant by finalizing a recommendation is only a part of the expected outcomes from the workshop. Identifying essential but missing component(s) in the research area, picking up valuable information and the latest numerical models that can be shared by research communities in both countries, and getting new ideas from discussions are expected and beneficial for participants. I hope the workshop will be fruitful, will be the seeds for the break through of science in this area, and will help the science to contribute for the society.

Prediction of Climate and Water Cycle Variability on Monthly, Seasonal and Annual Time Scales

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It is well-known that nonlinearity inherent in atmospheric dynamics limits the predictability of individual weather disturbances to two weeks at most (Lorenz, 1963). One hopes, however, that practically useful predictability should exist in slowly-varying components of climate variability, in which conditions "external" to the atmosphere play more dominant roles. Identification and understanding of such variability consist a major part of climate variability studies. In this talk, the issue of climate predictability on monthly, seasonal, to (inter-)annual time scales is reviewed with emphases on recent advances and areas for further development.

One of the fields that have seen striking development in terms of predictability is, of course, the El Niño-Southern Oscillation (ENSO). Thanks both to observing system development and successes in numerical modeling of the phenomenon due to a ten year international research project on Tropical Oceans and Global Atmosphere (TOGA), ENSO predictions for a few seasons ahead are now operational at many climate research institutions world wide. Especially, successes demonstrated by general circulation model-based forecasts for the historical 1997-98 El Niño event were quite impressive. The presently ongoing, weaker El Niño has also been predicted reasonably by many prediction systems. It appears that we are acquiring practically useful skill for predicting sea surface temperature (SST) anomalies in the El Niño monitoring areas about half a year in advance. Despite such an impressive development, however, there still remains so much uncertainty when one wishes to predict regional climate anomalies quantitatively; individual ENSO events exhibit so wide a variety in terms of onset, growth, decay, and extent of their influences. Precipitation anomalies, for example, are much more difficult to predict than the ENSO SST indices. Better understanding of atmospheric teleconnection mechanisms in response to SST and further advances in climate models are, of course, necessary, but understanding of other major modes of climate system variability, e.g., monsoon, and their interactions with ENSO should also be of critical importance.

Historically, the relationship between ENSO and Indian monsoon has been well recognized; indeed, the atmospheric branch of ENSO was discovered by Sir Gilbert Walker in his search for prediction indices for Indian monsoon variability. However, the ENSO-monsoon relation is still under active debate and its understanding is far from satisfactory. It seems that monsoon is an even more chaotic system than ENSO, and its variability demands quantitative assessments of not only remote ocean-atmosphere interactions, but also land-atmosphere and local ocean-atmosphere interactions as well. For example, the possibility of springtime Eurasian land surface conditions, such as anomalous snow cover, affecting subsequent monsoon intensity has to be verified quantitatively using comprehensive numerical models against other dominant influences, e.g., by ENSO. Some of recent research topics on this matter will be presented at the workshop.

East Asian countries, China, Korea, and Japan, are also subject to ENSO influences, but their extent differs from one event to another, and considerations of interferences between ENSO and other components of variability appear necessary. Recent investigations indicate the importance of a predominant pattern of moisture flux variability over the subtropical northwestern Pacific that can exist itself without recourse to underlying SST anomalies (SSTAs) but still can interact significantly with various local and remote SSTAs. As for the Indian monsoon variability, roles of intraseasonal variations in convective complexes in the Indo-Pacific regions and of local ocean-atmosphere interactions overt he Indian Ocean sector seem to require special attention.

There exist many more modes of variability in the global atmosphere that play dominant roles in monthly and longer time scales; many, so-called *teleconnection patterns* have been well-known and are believed to arise from dynamics internal to the atmosphere. One of them, called the Arctic Oscillation (AO), although there is controversy in distinguishing it from the North Atlantic Oscillation (NAO), has attracted renewed interests recently. We have made a dynamical analysis on the origin of its pattern formation dynamics to be able to show that it is one of the least damped modes of the wintertime climatology, and therefore, has the longest persistence; the persistence arises from a positive feedback between zonal mean winds and zonally asymmetric component of circulation anomalies. The AO/NAO not only affects European countries but also Eurasia. Dominance of the AO pattern in late winter affects low-level temperature anomalies over a broad are of the Eurasian Continent that persist during springtime and sometimes affect early summer conditions over the East Asia. On the other hand, there exists a lagged statistical relationship that the appearance of the AO pattern in winter tends to be preceded by eastern Eurasian snow anomalies. Such interactions between atmospheric intrinsic modes of variability and lower boundary conditions have to be clarified more extensively. Another example of such relation is decadal modulation of the NAO variability with North Atlantic SSTAs recently elaborated by ensembles of long-term atmospheric general circulation model integrations.

The authors have recently discussed a tropical axisymmetric mode of variability, called TAM, that is also a least-damped mode existing all the year and has an appearance of zonally symmetric height and wind variations confined in the tropical belt. Its dynamical origin, excitation by ENSO, and a possible role in ENSO teleconnection over the Eurasian area will be discussed at the workshop.

Helping Water Resource Management Face Global Change through Hydroclimatic Research: Pitfalls and Prospects

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Expectations for hydroclimatic research are evolving as changes in the contract between science and society require researchers to provide “usable science”. However, there has been disappointment in the extent to which improvements in hydroclimatic science from large-scale research programs have affected resource management policies and practices. Hydroclimatic research advances alone are insufficient for more extensive use of hydroclimatic information or better decision and societal outcomes. Research products are often ill-suited for direct use in decision making, while decision making is often ill-suited for use of that information. Overcoming barriers to use requires adaptation on the part of both the scientific and resource management communities.

Hydroclimatic researchers must focus on information relevance, accessibility, and credibility – from the perspective of prospective users. Relevance concerns the scale, extent, and timeliness of information. For example, researchers developing distributed hydrologic models require long-term systematic gridded products at high spatial and temporal resolutions, while operational forecasters require watershed-based areal precipitation estimates with real-time availability. Further, climate information is less useful to many decision makers than “downstream” information (e.g., snowpack, streamflow). Accessibility is more complex than availability, requiring knowledge about the cognitive and discursive frameworks of specific users. Accessibility requires balancing continual education of users as scientific capabilities evolve against waiting to develop information products until reaching scientific thresholds. Credibility encompasses both the actual and perceived information quality, and requires consistent reporting of product quality, although the challenge is significant in the absence of “true” values (e.g., areal precipitation, snow water equivalent). Further, credibility encompasses perceptions of sustainable access to new information. Based on experience, some decision makers are skeptical about committing scarce resources to incorporate new information without strong confidence that products will exist after several years of demonstration.

The water resources sector must adapt their decision processes to effectively exploit evolving scientific understanding and predictability. Better familiarity with scientific products is needed, especially regarding proper interpretation and understanding information uncertainty. Strategic planning is needed to explicitly identify which decisions can exploit extant research and products. Further, organizations must increase their operational flexibility, by explicitly considering hydroclimatic variability and change, and replacing incentives for crises response and possibly outmoded standard operating procedures with incentives for proactive management. However, use of even high quality information may ultimately be limited by unrelated factors (e.g., societal perceptions about the desirability of water supplies from different sources).

These issues are addressed in the context of on-going attempts to accelerate application of hydroclimatic research, including seasonal forecasts and remote sensing products, by water and watershed managers through Internet-based tools for acquiring and evaluating data from diverse sources. Because almost all resource management decisions require, implicitly or explicitly, some sort of hydroclimatic forecast, forecasts constitute an important link between science and society.

Each time a prediction is made, science must address and communicate the strengths and limitations of understanding. Each time a decision is made, managers must confront their understanding of information and an opportunity exists for making clear the importance of investments in scientific research. Additionally, a focus on interannual variability and seasonal forecasts helps individuals confront issues of scientific uncertainty and strategic planning without the negative connotations some associate with climate change.

Based on extensive interactions with the water resources sector, that revealed widespread confusion about seasonal forecast interpretation and skill, we have developed an on-line Forecast Evaluation Tool (FET) that exemplifies providing scientific data in a supportive context, transforming data into knowledge. The FET enables users to consider the regions, seasons, forecast lead times, and evaluation criteria relevant to their specific decision making situations. The FET accesses and analyzes data based on user input, but through layers of explanation and guidance (e.g., instructional webpages on interpretation of official climate outlooks with an interactive quiz to ensure users adequately understand the outlooks to use them appropriately). We also have developed Internet portals for satellite-based precipitation and snow cover estimates and mapping. Precipitation estimates are based on the PERSIANN system for combining data from multiple satellites using artificial neural networks; the estimates have been demonstrated to be more accurate, with higher spatial and temporal resolution (half-hourly over ¼ degree grid), than estimates obtained using other satellite precipitation algorithms. Fractional snow covered area (SCA) estimates are based on AVHRR or MODIS data, while snow water equivalent estimates result from merging ground measurements with SCA maps at ½ to 1-kilometer scales. The webtools have been designed and refined with substantial feedback from the water resources community using surveys, interviews, and workshops.

Diversity within the water resources sector presents a challenge for providing advanced data and information over the Internet. In our experience, advanced users are important in prioritizing information needs, while beginning users are important in determining how information should be communicated. Recognizing that many individuals lack Internet access, our web portal design includes capabilities for customized report generation so extension agents or other trusted information intermediaries can provide material to decision makers at meetings or site visits. Users can also organize and save their information and analyses requests in customized project folders to enable efficient access to updated products over the long term. However, design and implementation of commercial quality websites requires highly specialized technical personnel and timeframes that can be difficult to accommodate in many federally funded projects, and presents long-term sustainability challenges related to website maintenance and transferability.

Increasing the utility of hydroclimatic research is ultimately an interactive, iterative process involving researchers, forecasters, and decision makers over extended periods and multiple hydroclimatic events. Focusing on incremental improvements in scientific advancements provides opportunities for sustained interactions with the water resources sector as new products become available, and for more effective enumeration of the value of scientific advancements as reflected by improved predictability and impacts on resource management decisions. Progress in hydroclimatic research and water resource management is neither easy nor assured. However, working together offers opportunities for achievement unlikely to be realized independently.

Assessments of Water Supply and Demand

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The first comprehensive global water assessment "World Water Balance and Water Resources of the Earth" was published by UNESCO in 1974. It was assembled by the State Hydrology Institute (SHI) of USSR with support of UNESCO, WHO and other UN agencies. The UNESCO claim "all subsequent publications gave no new information as compared with the above studies" would be a fare statement.

The latest global assessment of water supply and demand is Igor Shiklomanov ed. "World Water Resources at the beginning of the 21st century" published by UNESCO in 1998. It was also assembled by SHI during 1991-96 under the framework of UNESCO IHP.

They used the river runoff approach, as opposed to the meteorological approach, to assess the freshwater, in the latter case, in 26 large "natural-economic regions" of the Earth. They claim that the meteorological approach (R=P-E) is too crude in majority of basins, especially arid and semi-arid regions. Also the meteorological method cannot yet estimate the seasonal availability and the inflow from the upstream water in the international rivers. They have used the 2500 stations of the river runoff measurement stations out of 40 000 stations at their disposal through WMO. The subject period was made common to 1921-1985. Where data are lacking, statistical correlation method was applied utilizing, in addition to river runoff, the meteorological data at more than 7000 stations.

The groundwater "related to river runoff" is treated as part of the river runoff. The part "not related to river runoff" is estimated as low as 5% of the total river runoff based on the African experiments by FAO in 1995 and treated as negligible on regional basis.

Although their assessment is very precious and valuable, there are several major areas of necessary improvements that need strong scientific support. They are:

1. It is necessary to develop a meteorology, hydrology and water resources integrated methodology to assess the water resources of the Earth. The assessment should be in a distributed way in time and space. Distributed hydrological models should be developed together with comprehensive GIS databases.
2. The groundwater resources should be properly assessed. The current efforts of IGRAC (International Groundwater Resources Assessment Center), Water Problems Institute of Russian Academy of Sciences, IAH etc. are important. GRACE is an important challenge for satellite use for groundwater assessment but the resolution is a hard barrier.
3. The assessment of reservoirs is also important. There is no reservoir database that provides the location coordinates and elevation-area information.
4. The lack of water use data is limiting the accuracy of the current and the future forecasts of water demand. The largest water use sector, agricultural irrigation, is especially poor in data. The industrial water recycling information is not available even in developed countries.

5. The assessment of virtual water, water transferred by trading goods, is also necessary to draw a true picture of water use by country and region and to make better forecast of water use.

Distributed hydrological models that can simulate hydrological dynamics of large basins from meteorological and land surface remote sensing data should be developed. Such models should be able to integrate meteorology, land surface processes, vertical as well as horizontal surface and subsurface flow and water withdrawal and return flow system reflecting detail hydrological parameters such as river width, riverbed roughness, infiltration, transmissivity, groundwater recharge/flow, snow pack/melt, water withdrawal/return, reservoir storage/control etc. Models that fit to such purpose are not well developed yet. The IAHS initiative PUB (Prediction in Ungaged Basins) is worth being supported for this purpose. A distributed hydrological model BTOPMC is under development for the Mekong and the Yellow basins.

Assessment of water withdrawal is an extremely difficult matter. Tremendous efforts may be necessary to collect and compile the ramified records that exist in various administrative branches into databases. A large number of reservoirs are playing the most important role in water use but their function is not enough monitored. Satellite monitoring of world reservoir storages is an important scientific agenda. It is necessary to create 4DDA data sets for hydrology including water use.

Long-term climate and water cycle variability and change – overview

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This talk addresses three broad questions: 1) What are the key modes of variability in the land surface branch of the water cycle? 2) How is the land surface water cycle changing? and 3) What are the implications of possible future changes in the water cycle for human use and water management? From the standpoint of the land surface hydrological cycle, precipitation is the most important driver. In terms of characterizations, key aspects of precipitation include its seasonal distribution, diurnal variability, storm scale statistics (for instance, interarrival time of storms, and the spatial structure of storms). In terms of runoff and streamflow, hydrologists have long characterized its statistical properties through use of frequency distributions, and related properties (e.g., moments) thereof. Typical textbook examples show that these methods work quite well for engineering design purposes, so long as the climate is "well behaved". However, this is not always the case, especially in areas where multiple mechanism may lead to exceptionally extreme events. As an example, the Pecos River flood of 1954 was about 10 times larger than the next largest event in the 40+ year record. No tractable frequency distribution will fit such a situation. Furthermore, in areas such as the U.S. Southwest where mixtures of monsoon precipitation and infrequent tropical storms lead to floods, the relative mix can be quite sensitive to climate variability (at e.g. decadal an longer scales).

A significant evolution in the characterization of hydrologic variability at the land surface is the beginning of an understanding of its interaction with interannual and longer scale climate variability. For instance, the strong ENSO signal along the west coast of North America is now widely recognized by planning agencies, even though most formal procedures for water management (e.g., flood control rule curves for reservoirs) are still unconditional. Similar work in Australia has shown the importance of the interaction of decadal variability (Pacific Decadal Oscillation and equivalent in the southern hemisphere) and interannual variability on flood frequency.

Although the frequency approach has a long history and is the basis for much, if not most, hydrologic design, the sequencing of events is of great scientific and practical interest. Two examples help illustrate this point. Both are decadal scale droughts with important consequences for water supply – one in western Australia (1970s-1990s), and the other in northern Mexico (early 1990s-present). In both cases, the average runoff over a period of a decade or more is around ½ of the mean of the entire historic record. The question which appears not to have been answered are whether such changes are an expected consequence of the amplification of precipitation sensitivity (essentially elasticity of runoff with respect to precipitation), such as would be reflected in interannual variability, or are there other feedbacks that may have resulted in intensification of the drought?

In terms of trends in the surface hydrological cycle, there is a wealth of information in the 2001 IPCC report and supporting references. In particular, a fairly comprehensive analysis of changes in annual and seasonal precipitation over the 20th century was produced for the IPCC. In general, the analysis shows a predominance of upward trends globally, with somewhat greater and more prevalent trends at high latitudes, punctuated by strong downward trends in equatorial Africa.

Less work has been done to evaluate trends in streamflow, and the results of the studies that have been conducted are somewhat mixed. For instance, a study of trends in unregulated U.S. stream gauges showed mostly upward trends in low to medium flows, but relatively few trends in high flows. On the other hand, a recent study of floods in very large rivers globally found a slight (statistically significant) increase in the latter portion of the observational record (typically most recent 40 years or so). Few observations of evapotranspiration exist over the long-term, however long-term observations of pan evaporation have been analyzed, especially in the U.S. and the former Soviet Union. Over the second half of the 20th century, there is strong evidence of downward trends in pan evaporation, which more or less coincide with downward trends in the daily temperature range, and increased cloud cover. A hypothesis has been advanced to the effect that actual and potential evaporation should be complementary, because when moisture stress reduces actual relative to potential evaporation, net radiation is only modestly affected, and what might be termed the "energy gap" (available energy less latent heat) goes primarily to sensible heat, which in turn is energy that would be available for evaporation of a free water surface, and in turn an increase in potential evaporation.

The possible impacts of climate change on land surface hydrology and water management have now been widely analyzed. The 2000 IPCC report and the U.S. National Assessment collectively reference over 100 such studies. Almost all use GCM output, downscaled in some manner to the river basin scale. Generally, the hydrologic, and hence water management effects, are tightly linked to projected GCM precipitation changes. These vary widely from model to model at the river basin level, notwithstanding general consistency, at least in terms of the direction of change (increasing) at the global level. One exception where there is more consensus is environments, such as the western U.S. and high latitude rivers, where much of the annual runoff is derived from snowmelt. In these environments, modest changes in temperature (e.g., of the order of a degree or two C in annual mean over the winter season) will result in shifts in the timing of the seasonal hydrograph peak. In two examples (Columbia and Sacramento-San Joaquin River systems), where reservoir systems are "small" (total storage well less than the mean annual reservoir inflow), such seasonality shifts would have major impacts on reservoir system performance. In a third example (Colorado River system), where reservoir storage is several times mean annual inflow, system performance would be substantially degraded by modest (order of 10%) reductions in the mean annual flow. However, even though seasonality shifts similar to those predicted for California and the Columbia systems are projected to occur, these shifts have little to do with the projected changes in reservoir system performance, which instead is dominated by changes in the mean annual inflows.

Japan's Progress in the Global Precipitation Measurement (GPM)

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As the famous IPCC report mentioned, the global warming is undeniable. One of the crucial issue associated with the global warming is the future variation of precipitation. Needless to say, precipitation is the major fresh water resource. Since the water demand increases due to the population increase and industrialization and modernization of the life style, even a small variation of precipitation has a big potential to jeopardize the basic environment of the human life. Prediction of the future variation of precipitation is a difficult but crucial task. In the last 100 years, the global precipitation seems to have increased by a few percents, but the increase is not so significant. The regional variation is large. For example, the precipitation in Japan shows slight decrease in the last 100 years. To monitor the precipitation variation, it is crucial to observe precipitation in global and local scales with high temporal resolution. Model development is remarkable in these years. Global non-hydrostatic models with a spatial resolution less than 10 km may applicable in the near future. Since the precipitation has a high variation in space and time, and model result of precipitation is sensitive to parameterization, etc, precipitation data is one of the major data for model validation and development. To meet the global precipitation observation requirement, Global Precipitation Measurement (GPM) has been proposed. The main objective of GPM is to provide three-hourly global precipitation maps. We will get much better precipitation climatology using the maps. The precipitation map will help to improve the global atmospheric structure and variation using the so-called 4DVAR data assimilation technique. We could also expect much better short-term weather forecast which will give a great benefit for disaster prevention.

GPM is based on the success of the Tropical Rainfall Measurement Mission (TRMM) which is a joint venture of US and Japan. TRMM was equipped with a rain package which consists of a single wavelength radar (PR), a microwave radiometer and a visible/infrared radiometer. The rain estimate using the microwave radiometer or a visible/infrared radiometer are tuned and improved using the direct rain estimate using the precipitation radar. The unique power of TRMM is the PR. PR is working exactly as expected. PR provided us the three-dimensional rain structure. PR data have only little difference in quality over land and ocean, which makes PR an invaluable rain sensor onboard a satellite. Thanks to the non-sun synchronous orbit along with the homogeneous data quality of PR, diurnal variation of precipitation was clearly revealed. The diurnal variation is significant in the tropical region which has clear land/ocean contrast. Generally speaking, morning rain is over ocean and afternoon rain is over land. It was known that shallow convection dominate in the east Pacific Ocean where there exists subsidence leg of Walker circulation. The range resolution capability of PR revealed the global distribution of shallow convection over ocean. Tall convection in the afternoon in monsoon Tibetan Plateau was also revealed.

GPM consists of a core satellite and a constellation of small satellites equipped with microwave radiometers. The core satellite will have a dual wavelength radar (DPR) and will be used to tune and train the microwave radiometer rain estimates. For the space segment of GPM, Japan plans to take a role of DPR development and launch of the core satellite. Currently, the National Space Development Agency of Japan (NASDA) is developing DPR with a collaboration of the

Communications Research Laboratory. Compared with tropical regions, mid- and high- latitude regions have weaker precipitation and snow or ice precipitation, and DPR which has a high sensitivity and a capability of discrimination of liquid and slid hydrometeors is required. The swath of the radar will remain as the TRMM precipitation radar. To improve much the sensitivity, we have several options for the higher frequency (Ka-band) radar, and we nearly decided to have a little bit poor range resolution of 500 m. The lower range resolution will help much to reduce receiver noise level. The radar swath is another issue. As the TRMM radar data analysis experience showed, the sampling is a great limitation. However, it is difficult to make wider the swath technologically. So, the swath of the lower frequency (Ku-band) radar of DPR will remain as the same as the TRMM radar. The higher frequency radar may have about 100 km.

Current concept of the core satellite is as follows:

Launch year: 2007

Mission life: 5 years

Orbit inclination: 65-70 degrees

Orbit altitude: about 400 km

Core sensors: dual-wavelength radar, TMI-like microwave radiometer

The major parameters of DPR are:
Frequency: 13 and 35 GHz (dual-wavelength)
Range resolution: 250 m (14 GHz), 250/500 m (35 GHz)
Horizontal resolution: about 5 km at nadir
Sensitivity: about 10 dBZ

The roles of Japan and the U.S. could follow the TRMM's way as:
Japan: radar, rocket launching
US: satellite bus, microwave radiometer

The algorithm development for DPR and a combination of microwave radiometers has also been started. GPM algorithms will be much complicated compared with TRMM. In addition to the TRMM type algorithms, we need DPR algorithms and constellation algorithms.

Development of a New Generation of Earth System Models

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General Circulation Models (GCMs) have provided many insights into the global climate system, but they have also pointed out their weaknesses in simulating properly the earth system at various scales. As some of these major weaknesses are imbedded in the fundamental concept that these models are based upon, and also due to the growing desire to understand the regional aspects of global change, a new generation of models based on a modern philosophy and commonly referred to as "Earth System Models" (ESMs), is under development. Among the few ESMs being proposed by the international community, the Ocean-Land-Atmosphere Model (OLAM) developed at Duke University offers a few unrivaled advantages, including a nesting capability to simulate various regions at various resolutions, a new coordinate system particularly advantageous in very complex terrain, and an unstructured grid to resolve (rather than parameterize) convection. It benefits from the physics developed and tested over the past 20 years as part of the Regional Atmospheric Modeling System (RAMS) and from the Ecological Demography (ED) model, which provides the capability to simulate vegetation dynamics and their interactions and feedback with the other components of the earth system.

Appendix D: Poster Abstracts

(*Alphabetically*)

Forecasting and Controlling Domestic Water Demand in an Urban Area

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In order to assess the sustainability of water use, it is necessary to forecast not only the water availability in future, but also change of water demand in future. There are various sectors in water use, and domestic sector does not consume much water comparing with other sectors, such as agriculture. However rapid urbanization happens in developing countries, rapid increase of domestic water demand is expected in urban areas of developing countries. Forecasting the change of water demand is important to assess the sustainability of water use in these areas.

The objective of this study is to develop the forecasting model of domestic water demand in various regions in the world, and to discuss how to control the water demand for sustainable water use.

Two types of analysis are ongoing for this objective. One is the analysis of historical change of water consumption in several cities for extracting the factors affecting the change of water consumption. The other is the comparison of water consumption and various indices among countries and regions for extracting the factors affecting the difference of per capita water consumption.

Per capita domestic water consumption is different in each city, country and region, even within the developed countries. These differences may depend not only on economic conditions, but also on various factors, such as climate condition, citizen's lifestyle, cultural background and so on. From the comparison of water consumption for each purpose in household among several countries, per capita water consumption in kitchen, toilet flushing and bathing was different in each country. This result suggests that citizen's lifestyle and cultural background may be important factors in addition to economic condition.

Numerical simulation of the water cycle change over the 20th century

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We have used numerical models to test the impact of the change in Sea Surface Temperatures (SSTs) and carbon dioxide (CO2) concentration on the global circulation, particularly focusing on the hydrologic cycle, namely the global cycling of water and continental recycling of water. We have run four numerical simulations using mean annual SST from the early part of the 20th century (1900-1920) and the later part (1980-2000). In addition, we vary the CO2 concentrations for these periods as well. The duration of the simulations is 15 years, and the spatial resolution is 2 degrees. We use passive tracers to study the geographical sources of water. Surface evaporation from predetermined continental and oceanic regions provides the source of water for each passive tracer. In this way, we compute the percent of precipitation of each region over the globe. This can also be used to estimate precipitation recycling. In addition, we are using the passive tracers to independently compute the global cycling of water (compared to the traditional, Q/P calculation).

Distributions-Oriented Forecast Verification of Ensemble Streamflow Forecasts

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Verification of probabilistic forecasts is an essential first step for operational use of forecasts in decision-making. With the distribution-oriented (DO) verification approach, the correspondence between forecasts and observations is modeled explicitly by their joint probability distribution. Aspects of forecast quality of interest in verification are derived from the joint distribution model. As originally developed, the DO approach assumes that both forecasts and observations are discrete random variables. Here, we extend the DO approach to deal with ensemble forecasts, where the forecast is a continuous probability distribution for an outcome that is a continuous random variable. Applications are shown for ensemble streamflow forecasts for the Des Moines River (Iowa) made using the National Weather Service (NWS) Advanced Hydrologic Prediction System (AHPS) and an experimental system. Some issues we have investigated using improved DO verification approaches include (1) bias-correction for hydrologic forecast models, (2) assessing forecast quality for rare events (low and high flow extremes) of interest to water managers, and (3) the impact of climate forecast information on streamflow forecast quality.

Water Resources Management Applications of USGCRP - GCIP Research Products in the Red-Arkansas River Basin

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Introduction

The US Global Climate Change Program – Global Energy and Water Cycles Experiment (GEWEX) Continental-scale International Project (GCIP) and the Department of Energy's Atmospheric Radiation Measuring (ARM) Program have improved understanding of the hydrologic cycle including:

- evapotranspiration
- precipitation forecasts
- surface runoff processes and streamflow forecasts

Much of this research is consolidated in the North American Land Data Assimilation System (NLDAS) project involving the comparisons of different Land Surface Models (LSMs), running model simulations in a near real-time setting, and using different data assimilation techniques to enhance the LSMs. This study will develop decision support system (DSS) applications for water resource managers. The Red-Arkansas River Basin is of particular interest because NOAA has also proposed this basin as a study site for UNESCO's Hydrology for the Environment, Life, and Policy (HELP) Program.

Approach

Improved methods for analyzing and predicting the consumptive use of water by irrigated crops and riparian vegetation are needed to make the optimal water management decisions. This effort will apply different NLDAS LSMs and their output to improve real-time decision making. The approach will validate:

- LSMs predicted variables using Oklahoma Mesonet observations, and integrate the results into Reclamation's Agricultural Water Resources Decision Support (AWARDS) System (Hartzell et al, 1998, 2000).
- Test the value of the research to improve North Fork Red River Basin management during drought in 2001-2002.
- Comparisons of the AWARDS system with and without the different LSMs output will test the benefit and value of this research to water managers.

Development of a High-Resolution Climate Model for Future Climate Change Projection on the Earth Simulator

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The fastest supercomputer of the world, the Earth Simulator (total peak performance 40TFLOPS) has recently been available for climate researches in Yokohama, Japan. We are planning to conduct a series of future climate change projection experiments on the Earth Simulator with a high-resolution coupled ocean-atmosphere climate model.

The main scientific aims for the experiments are to investigate 1) the change in global ocean circulation with an eddy-permitting ocean model, 2) the regional details of the climate change including Asian monsoon rainfall pattern, tropical cyclones and so on, and 3) the change in natural climate variability with a high-resolution model of the coupled ocean-atmosphere system.

To meet these aims, an atmospheric GCM, CCSR/NIES AGCM, with T106 (1.1deg) horizontal resolution and 56 vertical layers is to be coupled with an oceanic GCM, COCO, with 0.28deg x 0.19deg horizontal resolution and 48 vertical layers. This coupled ocean-atmosphere climate model, named MIROC, also includes a land-surface model, a dynamic-thermodynamic sea ice model, and a river routing model. The poles of the oceanic model grid system are rotated from the geographic poles so that they are placed in Greenland and Antarctic land masses to avoid the singularity of the grid system.

Each of the atmospheric and the oceanic parts of the model is parallelized with the Message Passing Interface (MPI) technique. The coupling of the two is to be done with a Multi Program Multi Data (MPMD) fashion. A 100-model-year integration will be possible in one actual month with 720 vector processors (which is only 14% of the full resources of the Earth Simulator).

Conclusions

Preliminary results are encouraging, and show potential water conservation benefits to drought mitigation, and integrated watershed management DSS, and sustainability.

Future Plan

We shall test these analyses and forecasts over the Lugert-Altus Irrigation District Red River Basin in Oklahoma, and shall extend them to the UNESCO-HELP Columbia Basin.

Prediction and Observation of Water Cycle Variability at Monthly to Interannual Time Scales

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Observation and prediction of water cycle variability for monthly and longer periods is key to understanding hydrology-climate interactions on human time scales. Here we present our recent research on the use of new satellite observing and model-predictive systems for characterizing variations in the regional and global hydrologic cycles. The first component of the presentation describes the potential of the new Gravity Recovery and Climate Experiment (GRACE) satellite to monitor changes in terrestrial hydrology. Applications to changes in total water storage, groundwater recharge and aquifer level variations, and water-balance estimates of evapotranspiration are presented for large (>200,000 km^2) watersheds. Second, we describe our recent efforts to provide optimal initial conditions for soil water states in the land surface component of climate models. Newly-constructed, multi-year, bias-corrected datasets are described, and the sensitivity of off-line land surface model simulations to forcing errors and differences is described. Implications for uncertainty in prediction of land model initial soil water conditions and coupled model interactions are discussed in the context of soil moisture memory.

A Framework for model verification using observations at a range of scales

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Model forecast verification to assess model performance and the need for further improvements is a foundational aspect of both atmospheric and hydrologic prediction. A variety of sensors (e.g. rain gauges, radars, and satellites) are used to monitor precipitation rate over the United States and provide both direct and indirect measurements at different scales and with different uncertainties. Physically-based numerical models, both of the atmosphere and the land surface, rely upon these observed data for model initialization, data assimilation as well as model verification. Owing to the tremendous scale-dependent variability of precipitation, merging or comparing observations at different scales, or comparing model outputs to observations, is anything but straightforward. In an effort to address issues associated with the scale discrepancy in merging or comparing information from multiple sources, this work proposes the use of a recently-developed scale-recursive estimation (SRE) framework for (1) QPF verification when observations are available at one or more scales different than the scale of the numerical model, and (2) derivation of merged products where observations and/or model outputs at different scales are combined to produce a single field for initialization, data assimilation or diagnostic studies. The proposed framework takes into account the multiscaling structure of precipitation and the scale-dependent uncertainty in the observations.

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Assessments of Potential Climate Forecast Benefits for Water Resources Management – A Quantitative Approach

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The aim of this research effort has been to assess the utility of climate information in the water resources management of reservoir systems. Earlier work has developed a prototype integrated forecast-control methodology for this purpose. It is the first end-to-end methodology to incorporate ensemble information from climate models, probabilistic downscaling and bias adjustment, reservoir inflow forecast ensembles, and a variable-scale, adaptive, stochastic-dynamical decision support system for the reservoir operation and management (*Georgakakos et al. 1998*). The reservoir module includes an assessment system that quantifies management benefits under varying operational plans or inflow forecast scenarios and at various risk levels. The system was developed and is being applied in close collaboration with users and management agencies.

In this presentation, the integrated methodology is applied to the management of the Folsom Lake reservoir in Northern California, operated for flood control, hydroelectric energy generation and water supply. Analysis uses ensemble forecasts from two different climate models, probabilistic downscaling procedures, and an adaptation of the operational hydrologic forecast model (see *Carpenter and Georgakakos 2001* and *Yao and Georgakakos 2001* for details). For the climate models, both AMIP-type simulation and forecast data are used. The analysis is done with historical data from the period 1964-1993 and for hypothetical future climate conditions. The results underline the importance of the decision support component for producing benefit from climate forecasts. Significant overall gain is shown in management benefits when uncertainty in forecasts is explicitly modeled by the forecast and the decision component. The poster quantifies the variation of these gains for the various forecast options. Current work focuses on a prototype implementation and demonstration project, called INFORM, which aims at facilitating the use of climate and hydrologic information for the management of the system of four large Northern California reservoirs (Folsom, Oroville, Shasta and Trinity).

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Yellow River Research Project
A study on the relationship between water cycle and human activities

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The Yellow River in China is quite important for the people living around it. The water of Yellow River is used for human life as industrial and drinking water , irrigation, etc. It has been reported in the last few decades that the Yellow River does not reach often to the sea. The reason for such a phenomenon is ascribed to natural and anthropogenic factors, and those interactions.

A Five-year research project has started this year to study the relationship between water cycle and human activities in the Yellow River basin from both viewpoints of natural and anthropogenic aspects. The main period to be studied is 1981-2000, during which economy and industry in China grew up rapidly and water and land uses have largely changed. In the same period, global warming was going on and it might affect water cycle on the earth. Rainfall, cloud and water vapor are investigated as well as radiation budget and evaporation on the surface, by using mainly meteorological and satellite data. Also a river basin model with 10km spatial resolution is developed, including meteorological and hydrological processes. The relationship between water resources availability and water management such as agricultural water use are investigated by field measurement and modeling studies. Those results will be used for the sub-grid scale parameterization in the river basin model.

An overview and details of the project will be introduced and discussed in the presentation.

Abstract For Poster by the NOAA/OGP Regional Integrated Sciences and Assessments Program for the US-Japan Workshop on Global Change: Climate and Water

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The poster presentation will discuss the lessons learned by NOAA's Office of Global Programs through its support of domestic U.S. integrated research related to the application of climate forecasting, and water science research to decision making processes. These lessons address issues related to spatial and temporal resolution in combination with underlying trends in land use, demographics, and water management.

In the case of spatial resolution decision makers information needs in the Southwestern United States agricultural sector will be presented. Climate information required by agricultural producers varies a great deal. A determining factor is the size of agricultural enterprise. These findings have implications for the tailoring of climate information to sub-sectors within an industry. Small scale producers require highly spatially resolved forecasts while larger scale producers require forecasts encompassing complementary and competitive producers' regions. The research provides insights regarding gaps in current regional scale climate forecast research and operational practices.

A second research topic to be presented is the potential impact of climate change on water management planning in the western United States. Snow water equivalent availability in the mountainous western United States is forecast to decline over the next century. This has implications for water managers, and the environment. A brief description of expected changes will be discussed. Two decision maker groups attempting to utilize this information The California Federal State Consortium to rehabilitate the San Francisco Bay Estuary (CALFED) and the Idaho Department of Water management will be considered.

Factors to consider regarding hydro-energy production optimization in the face of constraints of climate variability, environmental regulation, and flood control will be presented. This information considers research findings in California and the state of Washington. Lessons learned regarding groundwater management are to be discussed particularly in terms of planning for increased demand due to population increases.

Extreme event mitigation and adaptation will also be presented in terms of policy issues identified as being of importance to public and private sector managers. The primary extreme event presented will be drought. Examples of response to drought are provided in terms of demand, and supply management strategies, and coordination of the research community with decision makers.

Model Analysis of Atmosphere-Biosphere Carbon Exchange and Water-Use Efficiency

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Terrestrial plants assimilate atmospheric CO_2 at the cost of transpiratory water loss. Because of the intimate relationship, water use efficiency (WUE) of carbon assimilation by terrestrial vegetation (i.e. photosynthesis/transpiration) is critically important in considering ecosystem functions. In this study, a process-based model (Sim-CYCLE) is adopted to analyze water use efficiency of the terrestrial biosphere. The model contains a simple water budget scheme and mechanistic carbon dynamics scheme, and canopy gas exchange is scaled up from the single-leaf photosynthesis and transpiration. Stomatal conductance is derived from the Ball-Berry model, regulated by air humidity, ambient CO_2 level, and photosynthetic rate. Although few terrestrial carbon models regard river basin explicitly, this study recognizes world major river basins, based on three watershed maps. The estimated basin-scale water budget is examined by comparing with observed stream runoff data. The global simulation is performed at the spatial resolution of 0.5-degree for longitude and latitude, using an actual biome distribution map. The control simulation, in which equilibrium carbon and water budget is obtained, shows that globally, gross photosynthetic production is 130.0 Pg C yr^{-1} and total transpiration is 36.6 x 10^3 km^3: i.e. average WUE is 3.6 g C (kg $H_2O)^{-1}$. There appear obvious geographic gradients in leaf area index, canopy conductance, and photosynthetic and transpiratory rate. In the world major river basins, the Amazonian basin has the largest contribution to the global photosynthesis and transpiration, but with a low WUE of 2.2 g C (kg $H_2O)^{-1}$. These global and basin-scale estimations of water-carbon exchange may be implicative for water management to optimize carbon sequestration by the terrestrial ecosystems, and the process-based model will be used to evaluate the impact of global environmental change on land surface processes.

Nitrogen Flow in the Food Production–Supply System and its Environmental Effects in East Asia

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We created a numerical model to evaluate the anthropogenic nitrogen load on the environment and the nitrogen concentration in river water on a 0.5° by 0.5° scale. We estimated the nitrogen load of each country in East Asia from FAO statistics on fertilizer consumption, food balance sheet data, and grid data of NO_x emissions due to fossil fuel combustion. Nitrogen loads of each country were distributed among grid cells on the basis of farmland and population distributions. The concentration and riverine export of nitrogen in river water were calculated by assuming a first-order reaction model in which purification was a function of temperature and resident time. More than 90% of the nitrogen load originated from food production and supply. The contribution of NO_x emissions was important only in Japan and South Korea. The estimated load of nitrogen on the catchments of the major rivers was highly correlated with the measured riverine export of nitrate in the literature. Estimated nitrogen concentrations in river water that also agreed well with measurements, showed that rivers close to the east coast of northern and central China were highly polluted with nitrogen.

Prediction of Climate and Water Cycle Variability on Monthly, Seasonal and Annual Time Scales

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It is well-known that nonlinearity inherent in atmospheric dynamics limits the predictability of individual weather disturbances to two weeks at most (Lorenz, 1963). One hopes, however, that practically useful predictability should exist in slowly-varying components of climate variability, in which conditions "external" to the atmosphere play more dominant roles. Identification and understanding of such variability consist a major part of climate variability studies. In this talk, the issue of climate predictability on monthly, seasonal, to (inter-)annual time scales is reviewed with emphases on recent advances and areas for further development.

One of the fields that have seen striking development in terms of predictability is, of course, the El Niño-Southern Oscillation (ENSO). Thanks both to observing system development and successes in numerical modeling of the phenomenon due to a ten year international research project on Tropical Oceans and Global Atmosphere (TOGA), ENSO predictions for a few seasons ahead are now operational at many climate research institutions world wide. Especially, successes demonstrated by general circulation model-based forecasts for the historical 1997-98 El Niño event were quite impressive. The presently ongoing, weaker El Niño has also been predicted reasonably by many prediction systems. It appears that we are acquiring practically useful skill for predicting sea surface temperature (SST) anomalies in the El Niño monitoring areas about half a year in advance. Despite such an impressive development, however, there still remains so much uncertainty when one wishes to predict regional climate anomalies quantitatively; individual ENSO events exhibit so wide a variety in terms of onset, growth, decay, and extent of their influences. Precipitation anomalies, for example, are much more difficult to predict than the ENSO SST indices. Better understanding of atmospheric teleconnection mechanisms in response to SST and further advances in climate models are, of course, necessary, but understanding of other major modes of climate system variability, e.g., monsoon, and their interactions with ENSO should also be of critical importance.

Historically, the relationship between ENSO and Indian monsoon has been well recognized; indeed, the atmospheric branch of ENSO was discovered by Sir Gilbert Walker in his search for prediction indices for Indian monsoon variability. However, the ENSO-monsoon relation is still under active debate and its understanding is far from satisfactory. It seems that monsoon is an even more chaotic system than ENSO, and its variability demands quantitative assessments of not only remote ocean-atmosphere interactions, but also land-atmosphere and local ocean-atmosphere interactions as well. For example, the possibility of springtime Eurasian land surface conditions, such as anomalous snow cover, affecting subsequent monsoon intensity has to be verified quantitatively using comprehensive numerical models against other dominant influences, e.g., by ENSO. Some of recent research topics on this matter will be presented at the workshop.

East Asian countries, China, Korea, and Japan, are also subject to ENSO influences, but their extent differs from one event to another, and considerations of interferences between ENSO and other components of variability appear necessary. Recent investigations indicate the importance of a predominant pattern of moisture flux variability over the subtropical northwestern Pacific that can exist itself without recourse to underlying SST anomalies (SSTAs) but still can interact significantly with various local and remote SSTAs. As for the Indian monsoon variability, roles of intraseasonal variations in convective complexes in the Indo-Pacific regions and of local ocean-atmosphere interactions overt he Indian Ocean sector seem to require special attention.

There exist many more modes of variability in the global atmosphere that play dominant roles in monthly and longer time scales; many, so-called *teleconnection patterns* have been well-known and are believed to arise from dynamics internal to the atmosphere. One of them, called the Arctic Oscillation (AO), although there is controversy in distinguishing it from the North Atlantic Oscillation (NAO), has attracted renewed interests recently. We have made a dynamical analysis on the origin of its pattern formation dynamics to be able to show that it is one of the least damped modes of the wintertime climatology, and therefore, has the longest persistence; the persistence arises from a positive feedback between zonal mean winds and zonally asymmetric component of circulation anomalies. The AO/NAO not only affects European countries but also Eurasia. Dominance of the AO pattern in late winter affects low-level temperature anomalies over a broad are of the Eurasian Continent that persist during springtime and sometimes affect early summer conditions over the East Asia. On the other hand, there exists a lagged statistical relationship that the appearance of the AO pattern in winter tends to be preceded by eastern Eurasian snow anomalies. Such interactions between atmospheric intrinsic modes of variability and lower boundary conditions have to be clarified more extensively. Another example of such relation is decadal modulation of the NAO variability with North Atlantic SSTAs recently elaborated by ensembles of long-term atmospheric general circulation model integrations.

The authors have recently discussed a tropical axisymmetric mode of variability, called TAM, that is also a least-damped mode existing all the year and has an appearance of zonally symmetric height and wind variations confined in the tropical belt. Its dynamical origin, excitation by ENSO, and a possible role in ENSO teleconnection over the Eurasian area will be discussed at the workshop.

Water Resource and Its Variability in Asia in the 21st Century

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By the MEXT fund, we started a project “Water Resource and Its Variability in Asia in the 21st Century (FY2001-FY2003)” that consists of (1) Spatial and temporal interpolation of land-use and land surface environment, (2) Projection of global and Asian water circulation, and (3) Future perspective of variability of water resources in Asia based on climate projection. Six institutes (MRI, NIES, NIAES, CSIS/UT, IIS/UT, CRIEPI) are participating. By making most of the existing research framework for global water resource prediction, and also by considering seasonal changes in agricultural water demand and future changes in crops and/or land use due to climate variability, we assess the change of water supply/demand situation in Asia in the 21st century, paying attention to considerable interannual changes. Framework and current status of this project is shown.

In the second part of the poster, we introduce the MRI GCM, where a new land surface scheme was incorporated. The old scheme in our AGCM (MRI/JMA98) was a climate model version of SiB, with three soil layers and an explicit frozen soil water treatment. We implemented a new land surface scheme, in which the treatment of the snow is improved. A diurnal variability of the surface temperature over heavy snow regions was very small in the original model, but is improved very much. Some examples of precipitation extremes in global warming experiments are shown.

CEOP Annual Enhanced Observing Period Starts

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Toward more accurate determination of the water cycle in association with climate variability and change as well as baseline data on the impacts of this variability on water resources, the Coordinated Enhanced Observing Period (CEOP) was launched on July 1, 2001. The preliminary data period, EOP-1, was implemented from July to September in 2001. The first annual enhanced observing period, EOP-3, is going to start on October 1, 2002.

CEOP is seeking to achieve a database of common measurements from both in situ and satellite remote sensing, model output, and four-dimensional data analyses (4DDA; including global and regional reanalyses) for a specified period. In this context, a number of carefully selected reference stations are linked closely with the existing network of observing sites involved in the GEWEX Continental Scale Experiments, which are distributed across the world. The initial step of CEOP is to develop a pilot global hydro-climatological dataset with global consistency under the climate variability that can be used to help validate satellite hydrology products and evaluate, develop and eventually predict water and energy cycle processes in global and regional models. Based on the dataset, we will address the studies on the inter-comparison and inter-connectivity of the monsoon systems and regional water and energy budget, and a path to down-scaling from the global climate to local water resources, as the second step.

Intra-Seasonal Changes of Afternoon and Nocturnal Precipitation in Borneo as the Possible Proximate Cue of General Flowering

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Periodic droughts, cold snaps and elevated solar radiation have each been hypothesized to be the proximate cue required to initiate general flowering in the Dipterocarp forests in the South East Asian humid tropics. Recent study based on 10 years monitoring of tree phonology and precipitation around the Lambir Hills National Park, Sarawak, Malaysian Borneo (4°13' N 114°3' E) suggests that the periodic droughts, defined as consecutive 30 days period whose cumulative precipitation less than 20mm, have higher correlation with the general flowering events than the cold snaps. The diurnal variation of precipitation in this site has two distinct maxima, i.e. in the afternoon (13:00-15:00) and in the midnight (23:00-2:00) in both northeast and southwest monsoon season. These two maxima may be a result of cumulative effects by afternoon precipitation and nocturnal precipitation, which tend to occur over land and over sea respectively. Nocturnal maximum of convective activity was observed both northeast and southwest monsoon season around the northwest coast of Borneo. The intra-seasonal fluctuation of the 30 days cumulative afternoon and nocturnal precipitation from 1999 to 2002 was compared with the fluctuation of convective activity using the 5-day mean equivalent black body temperature (TBB) data from Japanese Geostationary Meteorological Satellite (GMS). The fluctuation of nocturnal precipitation has similar pattern with the TBB change. From the analysis of time-longitude sections of TBB suggests that the enhancement of convective activity by Madden-Julian Oscillation (MJO) may play an important role for determining the intra-annual variation in nocturnal precipitation in this site. On the other hand, the relationship between afternoon rainfall and TBB was not clearly seen. To predict periodical droughts and also general flowering, prediction of both afternoon and nocturnal precipitation is necessary. The understanding of the mechanism of diurnal change in precipitation over land, coast and sea is essential in this region.

On the Development of Regional Climate Change Scenarios For Assessing Hydrologic Impacts

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Regional climate models can be used to provide dynamical downscaling of global climate change scenarios. In the recent work funded by the Department of Energy Accelerated Climate Prediction Initiative (ACPI), a regional climate model based on the Penn State/NCAR Mesoscale Model (MM5) was configured using nesting to simulate regional climate of the western U.S. at 40 km spatial resolution. Long term simulations driven by the NCEP/NCAR and ECMWF reanalyses showed that the regional model reproduced much more realistically the mesoscale temperature and precipitation anomalies associated with the ENSO events in the western U.S. as compared to the global reanalyses. This highlights the importance of correctly representing climate sensitivity associated with changes in large-scale circulation and interactions with surface topography.

The regional model was used to downscale an ensemble of three global climate change simulations for the mid-century. Although downscaling did not significantly alter the regional mean changes in temperature and precipitation, differences in the spatial distributions between the global and regional simulations were sufficiently large to induce major differences in the surface energy and water budgets in river basins of the western U.S. An end-to-end assessment of climate change impacts on water resources further shows that differences between the global and regional climate change scenarios were significant enough to change the complexion of climate change projections on the Columbia River water resource system. To the extent that higher order spatial and temporal statistics are important to impact assessment, regional climate modeling provides an important tool for developing more realistic or sophisticated climate change scenarios that cannot be replicated by coarse scale climate projections.

Impact of Flood Variability on Sustainable Water Use in Monsoon Asia

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In the monsoon Asia, although agricultural water use shares a large part of the whole water usage, sustainable water use mechanism has been formed in agricultural water supply and use there. That is, from the viewpoint of watershed management, not only are the paddy areas having a function of flood regulation as a retarding basin (pond), but the rational supply of water resources is carried out by utilizing the natural hydrologic conditions. This function is commonly found in low-lying paddy areas such as paddies in Japan, Cambodia, Vietnam and other countries. Typical examples for this are found in the Mekong River Basin (drainage area: 790,000km^2, river length: 4,400km). However, the 2000-flood, which brought severe damage on riparian countries, brought disputes over the impact of world wide climate change on the Mekong area.

Then, this poster examines the behaviour and causes based on scientific explanations for the big flood in 2000. In addition, the uniqueness of the phenomena of this flood is shown by citing the relation between its topographic features and the concentration of flooding water in the lower flood-prone areas. The results obtained are summarized as follows: 1) Return periods of the 2000-flood are estimated as 3 – 10 years in Thailand and the Lao PDR, 20–60 years in Cambodia, and 30 years in Viet Nam; 2) The main causes of the 2000-flood are considered as the early start of rainfall by about 2 months, long-lasting heavy rainfall and the fulfillment of the storage capacity of Tonle Sap Lake and its surrounding low-lying areas in July; 3) The Mekong River has unique topographic features, so that rain water concentrated in the Tonle Sap area in Cambodia and the Delta area in Viet Nam; 4) In 2000, there were two types of floods, namely regional and flash floods. Both caused serious damage; 5) Early start of rainfall might be brought by the meteorological effect of La Nina phenomena in that year.

The California Water Resources Research and Applications Center

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The California Water Resources Research and Applications Center is a NASA-sponsored Regional Earth Sciences Applications Center and has been in existence since 1999. It produces short-term weather and stream flow predictions, seasonal climate and stream flow predictions, long-term climate change and impact assessments, and model evaluation and uncertainty analyses. We perform water quality and sediment related research and applications, including agriculture and economic impact assessments, real-time San Joaquin water quality monitoring, identification of contaminant runoff from abandoned mine sites, erosion modeling, sediment transport modeling, and probability analysis of potential hazards (e.g. landslides). Our Center has maintained a two-way flow of information between researchers and users, is a member of the Earth Sciences Information Partnership as an ESIP 2. We have contributed to the 2001 Intergovernmental Panel on Climate Change Third Assessment Report (IPCC TAR), the U.S. Global Change Research Programís national assessment on The Potential Consequences of Climate Variability and Change, and participated in numerous outreach activities.

We are working with Local Agencies (e.g. San Joaquin River Management Program, Central Region Water Quality Control Board, Southern Region Water Quality Control Board, Port of Los Angeles, Port of Long Beach), State Agencies (California Department of Water Resources, California Department of Conservation, California Department of Forestry and Fire Protection, California Energy Commission, Coordinated Resources Management Program), Federal Agencies (U.S. Geological Service, U.S. Bureau of Reclamation, U.S. Forest Service, NOAA National Weather Service-Sacramento, NOAA-California/Nevada River Forecast Center, NOAA-Office of Hydrology, NOAA NCEP Climate Prediction Center), and International Groups (Chinese Ministry of Water Resources, Queensland Department of Natural Resources, University of Queensland, Australia). We look forward to developing new partnerships with scientists and Agencies from Japan.

The U.S. Department of Energy Water Cycle Pilot Study:
Modeling and Analysis of the Water Cycle at the Walnut River Watershed, Kansas

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A multi-laboratory Department of Energy (DOE) team (LBNL, LANL, ORNL, ANL, BNL) has begun an investigation of hydrometeorological processes at the Whitewater subbasin of the Walnut River Watershed in Kansas. The Whitewater sub-basin is viewed as a long-term hydrologic research watershed and resides within the well-instrumented DOE Atmospheric Radiation Measurement/Cloud Atmosphere Radiation Testbed (ARM/CART). The focus of this study is the development and evaluation of coupled regional to watershed scale models that simulate atmospheric, land surface, and hydrologic processes as systems with linkages and feedback mechanisms.

Two overarching hypotheses are part of this pilot study: (1) Can the predictability of the regional water balance be improved using high-resolution model simulations that are constrained and validated using new water isotope and hydrospheric/land-surface measurements? (2) Can water isotopic tracers be used to segregate different pathways through the water cycle and predict a change in regional climate patterns?

New data from field measurements and satellites have been produced as part of this project. Isotope samples have indicated the extent of continental water recycling. Comparison of mesoscale model-simulated, radar derived, and observed precipitation for March 2000 has shown that the Penn State/NCAR Mesoscale Model version 5 performs well at 12km resolution, but has less variability at 4km. Hydrologic model scale studies using 30m resolution land surface characterizations and grids at 30m and 1km have shown that at the Whitewater subbasin, a semi-distributed model performs as well as a fully distributed model.

An Atmosphere-Soil-Vegetation Model to Simulate Heat, Water and CO_2 Exchanges Between the Atmosphere and Land Surface

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A new atmosphere-soil-vegetation model was developed to study heat, water, and CO_2 exchanges between the atmosphere and land surface. The model consists of one-dimensional multi-layer sub-models for atmosphere, soil, and vegetation and radiation schemes for the transmission of solar and long-wave radiation fluxes in the canopy. The atmosphere sub-model solves prognostic equations for horizontal wind components, potential temperature, specific humidity, fog water, CO_2 concentration, and turbulence statistics by using a second-order closure model. The soil sub-model deals with the vertical transport of CO_2, heat, and water in liquid and gas phases. The vegetation sub-model calculates CO_2, heat, and water exchanges at leaf surface based on the leaf photosynthesis. In the radiation schemes the solar radiation flux is partitioned into four components: visible and near-infrared bands in direct and diffuse components, and each component is calculated separately.

The model performance was tested by comparing surface fluxes of heat, radiation, and CO_2, radiometric surface temperature (skin temperature), soil temperature and moisture simulated by the model with measurements of the first field program in 1997 of the Cooperative Atmosphere-Surface Exchange Study (CASES-97). Comparisons between calculation and observations were carried out for some winter wheat fields and grasslands. During the calculation period from April 20 to May 21, winter wheat grew taller and grassland changed from brown (dead leaves) to green (active leaves) all around. The model simulated diurnal variations and one-month changes in observed heat and CO_2 fluxes satisfactorily.

The model was also coupled with an atmosphere model on trial. The Pennsylvania State University and NCAR mesoscale model (PSU/NCAR-MM5) was used for this test coupling. Two models were coupled by exchanging their outputs by using the message passing interface (MPI) on their independent parallel calculations. In this test, reasonable calculated values proved proper data exchanges by MPI and usefulness of this coupling method.

Cold Region Processes and Climate

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Cryosphere is one essential component in the climate system. They play an important role in the various processes for water/heat cycle and have influence to the material cycle. One of the aspect which is considered as important phenomena is the hydro-climatological process on the continental regions related to the snow cover and permafrost interacting with vegetation and other surface components.

The study on these aspects has been done as part of the study of Siberian Regional project in GAME (GEWEX Asian Monsoon Experiment) and FORSGC since 1996 and after. In these studies, three local observational sites (1 to few tens km^2) were established within the Lena River Basin and the characteristics of the water/energy exchange were investigated. Aircraft measurement on regional fluxes and boundary layer conditions were investigated. Verification and development of hydrological and land surface models were made based on these observation and developed data-sets. In FORSGC, additional research site was established in northern Mongolia to investigate regions in the southern limit of snow cover and permafrost region. Experimental studies to develop better cold region precipitation data-base and development of advanced land surface scheme considering typical cold region process such as drifting snow are also being done.

These studies have been advancing the understanding of the climatic role of cryospheric components, and will be advanced further related to the WCRP CliC(Climate and Cryosphere) Project in the future.

Influence of Soil and Vegetation on Rainfall in Coastal Desert and Mountainous Area Near the Red Sea

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The spatial and temporal distribution of rainfall variability is crucial in determining the socioeconomic conditions in the arid regions of the world. A reliable prediction of the rainfall variability is thus an important component of a disaster mitigation system. In addition, analysis of the underlying processes of such natural variability in the regional hydrological cycle provides clues to understand the mechanism of the desertification. In the present study, we discuss the region called "Asir" in the southwestern part of the Kingdom of Saudi Arabia to understand the influence of soil and vegetable on the rainfall variability. The Asir region enjoys a relatively good seasonal rainfall in spring and summer. Some stations at the higher altitude near the Red Sea coast record the country's highest rainfall. For example, three stations, Al-Amir, Abha and Beljurshi, have annual rainfall of more than 360 mm with relative humidity of more than 80%.

The southern part of the study region exhibits higher amount of interannual variability, most of which is confined in the first half of a year. The tropical climate variability from the Indian and Pacific Oceans, *viz*. the Indian Ocean Dipole and the El Niño-Southern Oscillation, dominantly influence the rainfall patterns through the atmospheric teleconnections. Besides, the changes in the Mediterranean Sea and the variability originating from the extra-tropical regions are found to influence the rainfall anomalies of the region.

We are now undertaking numerical simulations of rainfall and meteorology using a regional atmospheric model (RAMS) and NCEP data in 2000, under three kinds of soil and vegetation conditions; the first one is the validation simulation with the present "desert" condition, the second and the third are for "low grass" and "short tree" conditions respectively in a control area of 5625 square kilometers. The most powerful computer called the "Earth Simulator" provides us a scope to resolve complicated terrains and complex surface conditions in supper-high resolution (1km x 1km), using our original parallel computing scheme called "Time Splitting" method. The TS method divides a total simulation period into a combination of the same number of simulation tasks as the number of CPU clusters, and performs each task of a fine grid independently with initial and boundary conditions supplied from a large grid simulation of the conventional nesting scheme. The computational speed of TS method is linearly proportional with the number of CPU clusters.

Together with this regional modeling effort, we will include in our study a range of ocean and atmosphere models with regional to global extent. The synergic effort will provide us a better basis for understanding as well as predicting the climate variability in the study region. The knowledge gained from the study will be helpful in designing a new system for ameliorating socioeconomic as well as agricultural conditions in semi-arid and arid regions.

GCIP Water and Energy Budget Synthesis

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As part of the World Climate Research Program's (WCRP's) Global Energy and Water-Cycle Experiment (GEWEX) Continental-scale International Project (GCIP), a preliminary water and energy budget synthesis (WEBS) was developed for the period 1996-1999 from the "best available" observations and models. Besides a summary paper, a companion CD-ROM with more extensive discussion, figures, tables, and raw data is available to the interested researcher from the GEWEX project office, the GAPP project office, or the first author. An updated online version of the CD-ROM is also available at http://ecpc.ucsd.edu/gcip/webs.htm/.

Observations cannot adequately characterize or "close" budgets since too many fundamental processes are missing. Models that properly represent the many complicated atmospheric and near-surface interactions are also required. This preliminary synthesis therefore included a representative global general circulation model, regional climate model, and a macroscale hydrologic model as well as a global reanalysis and a regional analysis. By the qualitative agreement among the models and available observations, it did appear that we now qualitatively understand water and energy budget budgets of the Mississippi River Basin. However, there is still much quantitative uncertainty. In that regard, there did appear to be a clear advantage to using a regional analysis over a global analysis or a regional simulation over a global simulation to describe the Mississippi River Basin water and energy budgets. There also appeared to be some advantage to using a macroscale hydrologic model for at least the surface water budgets.

Regional Water Balance Studies Using Model-Data Intercomparisons

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Realistic simulation of regional water cycle dynamics is a critical test of the skill and utility of global climate change modeling. This challenge is one of the primary focuses of global change research at Oak Ridge National Laboratory (ORNL). To examine the performance of earth system models, we are studying: 1) predictions of continental freshwater flux to oceans, 2) the temporal pattern of residuals in water balances at river basin scales, and 3) global patterns of climate regimes clusters. The discharge of freshwater from large rivers is an important link in climate feedbacks among land, oceans, and atmosphere. We are currently evaluating the performance of the Community Climate System Model, version 2 (CCSM2) in comparison to pervious models and observational data. Results show that CCSM2 simulates freshwater fluxes better than the previous Community Climate Model, version 3, and produces annual hydrographs similar to most large rivers. We are also studying regional water balances in large river basins to see how well the water cycle is closed. Residuals of unaccounted surface water typically exist in both models and observed data, as demonstrated at the ARM-CART site in Kansas-Oklahoma and in the upper Tennessee River basin. Developing a better understanding of these residuals is essential in improving model performance. We are also using multivariate geographic clustering to visualize and detect patterns in model outputs. For example, business-as-usual simulations from the Parallel Climate Model have been diagnosed using this technique to define characteristic climate regimes for any geographic location on the globe, defined as the combination of precipitation, temperature, and soil moisture. These studies are part of a larger project exploring feedback mechanisms in the current generation of earth system models, supported in part by internal LDRD funding.

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Variation of Precipitation in the Indochina Peninsula

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Mechanisms of the diurnal and the 10-20 day variations of precipitation in the Indochina Peninsula are studied using non-hydrostatic cloud-resolving numerical models (CRMs), radar echo data, GMS Tbb data and reanalysis data.

Starting from a climatic initial conditions, 2D CRM successfully simulates the diurnal variation of precipitation. In the model, convections are activated at the lee-side foot of two mountainous regions located at the west and middle of Thailand in the evening of each day. The activated clouds are organized into squall lines that travel eastward during the night at about 5-10 m s -1 and govern the diurnal variation of precipitation in the eastern (leeward) area of mountains in the southwesterly monsoon season. These squall lines weaken around midnight. Diurnal variation of GMS Tbb data supports this mechanism.
Using multiyear radar echo data, the followings are revealed: 1) Echo rich areas shift leeward of main mountain rage in Thailand in monsoon season. 2) Radar echoes appear over mountains moved leeward and dominate the diurnal variation of precipitation in lee side plain areas.

It is concluded that the solar-synchronized life cycle of the squall lines and their eastward movement cause the nighttime maximum of the precipitation over the inland area of the Indochina Peninsula.

One of significant variations of precipitation whose periods are longer than one day is a 10-20 day variation. Using rain gauges, GMS Tbb and GAME reanalysis data, it is found that the 10-20 day variation of precipitation in the Indochina Peninsula is related with an n=1 first baroclinic equatorial Rossby wave. The wavelength of this wave is about 6000 - 7000 km and the equivalent depth is about 70 m. In 1998 rainy season case, this variation is significant in the latter half of the rainy season.

The International Model Parameter Estimation Experiment (MOPEX)

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The goal of Model Parameter Estimation Experiment (MOPEX) is to investigate techniques for the a priori parameter estimation for land surface parameterization schemes of atmospheric models and for hydrologic models. A comprehensive database has been developed which contains historical hydrometeorologic time series data and land surface characteristics data for 435 basins in the United States and many international basins. A number of international MOPEX workshops have been convened or planned for MOPEX participants to share their parameter estimation experience. The Second International MOPEX Workshop was held in Tucson, Arizona, April 8-10, 2002. The Third International MOPEX Workshop will be held during the IAHS/IUGG meeting in Sapporo, July 7-9, 2003 (workshop HW08). This paper presents the MOPEX goal/objectives and science strategy. Current status of the data base is summarized. Example results from our participation in developing and testing of the a priori parameter estimation procedures for the National Weather Service (NWS) Sacramento Soil Moisture Accounting (SAC-SMA) model and the Simple Water Balance (SWB) model are highlighted. Potential contributions of MOPEX to the IAHS Prediction of Ungaged Basins (PUBs) initiative are explored.

Global Change Impacts on Extremes in Hydrology and Water Resources

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This paper suggests the importance of research on extremes that would be caused by global climate change in the future. Extreme events are occurring every year all over the world, bringing serious disasters such as floods and droughts. Climatic studies so far have been focusing mainly on "climatic" values averaged over a number of years simulated, and have not shown extreme values which could be obtained by the global climate models. It is often said that severe storms would become stronger and more concentrated in time and space and that severe water shortages would take place in wider areas on the earth and in longer period of time. This tendency should bring severer water-related disasters in many places on the earth.

Reviewing recent investigations on climatic change impacts on hydrology and water resources in Japan, the author presents main outcomes from the investigations on hydrologic responses under some warming scenarios in a number of Japanese river basins and on global surface water distribution obtained by GCM experiments.

On the basis of meteorological and hydrological observations, this paper also reviews recent meteorological trend and flood and drought disaster situations in Japan, as well as in Eastern Asia region.

The technical discussion would include:

- Statistics of extreme meteorological and hydrological events and historical maximum records being introduced;
- Probable maximum precipitation (PMP) the depth-area-duration analysis (DAD) based on historical extreme values, radar rain gage observations and nonlinear optimization techniques
- Probable maximum flood (PMP/PMF) estimation using a grid-cell distributed hydrological model.

The importance of estimating probable extreme events and disasters based on physically based approach is stressed under global changing situations.

A Strategy for monitoring continental water budgets for global water cycle research

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Predictions from climate modelling, including the IPCC assessments indicate that climate change due to anthropogenic greenhouse gases will lead to global warming and an acceleration of the hydrological cycle. Understanding the change to the hydrological cycle is a central theme of the World Climate Research Programme's Global Energy and Water Cycle Experiment (GEWEX) as well as U.S. agency research plans, such as NASA's Earth Science Enterprise (ESE) and NOAA's Office of Global Programs. IPCC model results are quite strong for surface temperature changes, but are more uncertain with regard to precipitation and related hydrological fluxes. In this presentation we investigate how a global monitoring strategy can be designed to observe the terrestrial water cycle at continental scales. Using historical observations, off- line hydrologic model output of global simulations and NCAR PCM past and projected climate simulations, it is shown that decades to more than a century may be required to detect changes in the hydrological fluxes at large scales. The presentation also suggests a strategy for designing the location of 'indicator' basins that could be properly instrumented for a global 'climate change detection network.' Results of where these would be located, and their performance relative to the GEWEX Continental Experiment Scale (CSE) basins in the Americas, are presented.

Integration of Satellite Observations with Land Surface Models for Climate and Water Research

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In the past few years, my research group has been acting as a bridge linking the remote sensing and field experiment community with the weather and climate prediction and modeling community. Our efforts focus on: (a) developing and applying satellite and surface observations to the modeling of the land surface component of the climate system, and (b) reformulate and improve land models to optimally use remote sensing data.

Land surface model development: The community land model (CLM) has been developed by six U.S. land groups under our coordination (1998-2000) (Dai et al. 2003) and has been coupled with the NCAR climate model (Zeng et al. 2002). Compared with the original NCAR land surface model, CLM significantly improves the climate simulation of land surface air temperature and the water cycle. CLM has been implemented as the biophysical component in the NCAR CCSM2 and the NASA DAO. A consistent formulation has also been developed for atmospheric turbulence over land (bare soil, under and above canopy) and ocean (Zeng and Dickinson 1998; Zeng et al. 1998a, 2003a). This formulation significantly improves the simulation of surface skin temperature and energy balance in arid and semiarid regions. It has been implemented into CLM.

Land data development: We have developed global 1-km fractional vegetation cover (FVC) dataset for three years (1992 based on AVHRR and 2000-2002 based on MODIS) and 9-km FVC data for 19 years (1982-2000 based on AVHRR) (Zeng et al. 2000, 2003b). These data have been evaluated using field survey data and higher-resolution aircraft and Landsat data, and are implemented in the NASA Land Data Assimilation System. Vegetation root distribution data have also been developed for direct use in any land model (Zeng et al. 1998b; Zeng 2001). These root data significantly improve the offline simulation of surface water balance, and affect global and regional land-atmosphere interactions. This dataset has been implemented into the ECMWF operational model and CLM. A comprehensive high-resolution land data [FVC, LAI, roughness length, zero-place displacement, vegetation root distribution, albedo, and soil] have also been developed for use in regional and global models (Zeng et al. 2002).

Appendix E: Acronyms

ACPI	Accelerated Climate Prediction Initiative
ADEOS	Advanced Earth Observing System
AGCM	Atmospheric Global Circulation Model
AHPS	Advanced Hydrological Prediction System
AMIP	Atmospheric Model Intercomparison Project
AMSER	Advanced Microwave Sounding Radiometer
ANL	Argonne National Laboratory
AO	Arctic Oscillation
ARM/CART	Atmospheric Radiation Measurement/Cloud Atmospheric Radiation
AVHRR	Advanced Very High Resolution Radiometer
AWARDS	Agriculture Water Resources Decision Support
BNL	Brookhaven National Laboratory
BTOPMC	Block wise use of TOPMODEL with Muskingum-Cunge flow routing method
CASES	Cooperative Atmospheric-Surface Exchange Study
CCSM2	Community Climate System Model, version 2
CCSP	Climate Change Science Plan
CEOP	Coordinated Enhanced Observing Period
CERES	Clouds and the Earth's Radiation Energy System
CliC	Climate and Cryosphere Project COCO
CLIVAR	Climate Variability and Predictability Program
CLM	Common Land Model
COP	Conference of the Parties
CREST	Creative Research for Science and Technology
CRMS	Cloud Resolving Models
CSE	Continental Scale Experiment
CSRM	Convective System-Resolving Model
CUASHI	Consortium of Universities for the Advancement of Hydrologic Sciences, Inc.
DAD	depth-area-duration analysis
DHEM	Distributed Hydrological Environmental Model
DO	distribution oriented
DOE	Department of Energy
DPR	Dual Precipitation Radar
ECMWF	European Center for Medium Range Weather Forecasting
ED	Ecological Demography
ESE	Earth Science Enterprise
ESM	Earth Simulation Model
FRSGC	Frontier Research System for Global Change
DPR	Dual Wavelength Radar
FET	Forecast Evaluation Tool
GAME	GEWEX Asian Monsoon Experiment
GAPP	GEWEX Americas Prediction Project
GCIP	GEWEX Continental-scale International Project
GCM	General Circulation Model
GCOM	Global Change Observation Mission
GCSS	GEWEX Cloud Systems Study
GEWEX	Global Energy and Water Cycle Experiment

GHP	Global Hydrometeorology Project
GMS	Geostationary Meteorological Satellite
GPCP	Global Precipitation Climatology Project
GMS	Geostationary Meteorological Satellite
GPM	Global Precipitation Model
GRACE	Gravity Recovery and Climate Experiment
GSWP	Global Soil Wetness Project
GWC	Global Water Cycle
HELP	Hydrology for the Environment, Life and Policy Program
HyDIS	Hydrological Data and Information System
IAEA	International Atomic Energy Association
IAH	International Association of Hydrogeology
IAHS	International Association of Hydrological Sciences
IARC	International Arctic Research Center
IFPRI	International Food and Policy Research Institute
IGBP	International Geosphere-Biosphere Program
IGOS	Integrated Global Observing Strategy
IGRAC	International Groundwater Resources Assessment Center
IPCC	Intergovernmental Panel on Climate Change
IPCC TAR	IPCC Third Assessment Report
ISARM	Internationally Sared Aquifer Resources Management
ISLSCP	International Satellite Land Surface Comparison Project
ISSCP	International Satellite Comparison Project
IUGG	International Union of Geodesy and Geophysics
IWMI	International Water Management Institute
JIIHP	Joint International Isotope Hydrology Program
LBNL	Lawrence Berkeley National Laboratory
LSM	Land Surface Model
LUCC	Land Use and Land Cover
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MJO	Madden-Julian Oscillation
MODIS	Moderate Resolution Imaging Spectroradiometer
MOLTS	Model Output Location Time Series
MOPEX	Model Parameter Estimation Experiment
MPI	message passing interface
MPMD	multiprogram multidata
NAO	North Atlantic Oscillation
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NIES	National Institute for Environmental Studies
NLDAS	North American Land Data Assimilation System
NOAA	National Oceanographic and Atmospheric Administration
NSF	National Science Foundation
NSIPP	NASA Seasonal-to-Interannual Prediction Project

NWS	National Weather Service
OLAM	Ocean-Land-Atmosphere Model
ORNC	Oak Ridge National Laboratory
PERSIANN	Precipitation Estimation from Remotely Sensed Information Using Artificial Neural Networks
PMF	probable maximum flood
PMP	Probable maximum precipitation
PR	Precipitation Radar
PUB	Prediction in Ungauged Basins
RAM	Regional Atmospheric Model
RAMS	Regional Atmospheric Modeling System
SAC-SMA	Sacramento Soil Moisture Accounting Model
SAHRA	Sustainability of Semi-Arid Hydrology and Riparian Areas
SBSTA	UNFCCC Subsidiary Body for Scientific and Technological Advise
SCA	Snow Covered Area
SHI	State Hydrology Institute (Russia)
SMIP	Seasonal forecasting Model Intercomparison Project
SRE	Scale-recursive estimation
SST	Sea Surface Temperature
SWB	Simple Water Balance Model
TAM	Tropical Axisymmetric Model
THC	Thermohaline circulation
TMI	TRMM Microwave Imager
TOGA	Tropical Oceans and Global Atmosphere
TRMM	Tropical Rainfall Measurement Mission
TS	Time splitting
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USGCRP	U.S. Global Change Research Program
VIRS	Visible and Infrared Scanner
WCRP	World Climate Research Project
WEBS	Water and Energy Budget Synthesis
WGNE	Working Group on Numerical Experimentation
WSSD	World Summit on Sustainable Development
WUE	Water Use Efficiency

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